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Intermodal Efficiency of the Vancouver-Victoria Bus/Ferry Service and a Baseline Design for a Canadian Double-Deck Bus

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by
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November, 1981

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INTERMODAL EFFICIENCY OF THE VANCOUVER-VICTORIA BUS/FERRY SERVICE AND A BASELINE DESIGN FOR A CANADIAN DOUBLE-DECK BUS

by

T. Partridge, G. Taylor, L. Walker

November 1981

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre.

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17. Abstract

This study generated and evaluated technically and economically feasible courses of action to improve the intermodal system efficiency of the Vancouver-Victoria bus/ferry service.

The existing service was examined and compared to four alternative service options: a full shuttle system; a semi-shuttle system; a system with a double-deck bus fleet; and a mixed fleet system (single and double-deck buses). The last option, mixed fleet, is the recommended option for the most convenience/least overall costs.

A subsequent examination of the feasibility of a double-deck bus in Canada concluded that it is possible to build such a vehicle using state-of-the-art techniques. A baseline design for this vehicle is provided and the development and unit costs are estimated.

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17. Résumé

Cette étude traite de la conception et de l'évaluation des moyens techniques et économiques d'améliorer l'efficacité du système intermodal de transport par autobus/traversier entre Vancouver et Victoria, en Colombie-Britanique.

Le service actuel a été étudié et comparé aux quatre options alternatives suivantes: un service intégré de navette; un service de semi-navette; un service d'autobus à impériale et un service mixte d'autobus conventionnels et à impériale. Cette dernière option, le service mixte, est recommandée, puisqu'elle est la plus avantageuse en regard du service et des coûts d'opérations.

Une étude ultérieure de la faisabilité de l'utilisation d'autobus à impériale, au Canada, conclut à la possibilité de construire un tel véhicule, en recourant aux meilleures techniques actuellement connues. Un concept de base de ce véhicule est proposé et les coûts unitaires de sa fabrication sont estimés.

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SUMMARY

The objective of this study was to generate and evaluate technically and economically feasible courses of action to improve the intermodal system efficiency of the Vancouver-Victoria bus/ferry service. This report combines the work performed by two firms: Hickling-Partners evaluated cost-effective options to improve efficiency and Hovey & Associates analyzed the recommended option.

The existing scheduled bus/ferry service between Vancouver and Victoria is examined, and compared to four alternative service options. The major deficiency in the existing service is the incapacity of the ferries to handle overload scheduled coaches during the peak season of July and August. The comparison of alternatives is summarized in the Table below.

EVALUATION SUMMARY TABLE

	Option A Existing System	Option B Full Shuttle	Option C Semi Shuttle	Option D Double Decker	Option E Mixed Fleet
Annual Hourly Cost	1908	1300	1673	1388	1484
Annual Distance Cost	485	576	524	424	402
Annual Toll Cost	628	0	382	457	482
Annual Veh. Cost	482	352	417	868	618
Sub Total Operating	3501	2228	2996	3137	2966
Baggage "Pup" Cost	0	*	0	0	0
Tr * and Shop Cost	?	?	?	?	?
Terminal Cost		**	*		
Capacity	Worst	Best	Good	Good	Good
Passenger Convenience	Good	Poor	Fair	Good	Good
Reliability	Good	Poor	Fair	Good ?	Good ?

* All costs in ($000)

Option A is the status quo bus/ferry service.

A full shuttle system option B, with no buses, and only baggage "pups" going on board the ferries would provide the best solution to the capacity problem, would have the lowest direct bus system operating costs but provide the least passenger convenience. These cost advantages would be eroded to some extent when the cost of baggage "pups" and the cost of pick-up drop-off terminals are included. Even with these facilities, this system, while technically

feasible, would be inconvenient for passengers, and would present difficult scheduling problems for the operator.

A semi-shuttle system, Option C, with half the coaches operating as shuttles and the remaining buses, carrying all the luggage, boarding the ferries for the complete journey, would improve the capacity problem that now exists. However after adding in terminal costs, it would likely cost as much as the existing system and present additional customer confusion and operator scheduling problems.

A system operating as at present with a full fleet of double-deck buses, Option D, would give all the convenience of the existing system, and perhaps at lower cost in the long run, depending on costs and the feasibility of coach conversion for baggage handling. Double-deck buses would also increase passenger capacity of the present system by 50% with 12 m coaches and up to 100% with 14 m coaches.

A mixed fleet of double-deckers and standard buses, Option E, may be the best overall solution. Using a limited fleet (about 13 double-deckers) operating full time to provide the base off-season service, and then switching them to provide only peaking capacity. In the rush hours of the peak season, with the base service provided by standard buses, this would be an ideal application for high cost high capacity buses, the latter equipment being the lead coach. The length of double-deckers would make them more appropriate than 18 m articulated vehicles for the capacity problems of the ferry system. This system would have all the convenience features of the existing system, and based on preliminary costing appears to be the second least expensive system to operate, and may be the least expensive overall with all costs calculated.

A subsequent examination of the feasibility of building a double-deck bus in Canada concluded that it is entirely possible to build such a vehicle using entirely state-of-the-art techniques. A baseline design for this vehicle is provided and the development and unit costs are estimated.

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1. INTRODUCTION

This report evaluates a number of bus/ferry system options to improve intermodal efficiency of the Vancouver-Victoria service operated by Pacific Coach Lines Limited (PCL) in conjunction with British Columbia Ferry Corporation. This route has the highest passenger volume of any intercity bus route in Canada and, especially during the July/August peak period, experiences problems of insufficient capacity, equipment imbalance, congestion and other inefficiencies. Similar problems are being encountered an PCL's Fraser Valley route. An annual traffic growth rate of 9% on the Vancouver-Victoria route (19% on the Nanaimo-Vancouver route), 125 aging but well-maintained, low-mileage buses, 230 highly paid drivers and an operating deficit of $7 million all compound the system inefficiency and limit the alternatives for the improvement which is urgently needed.

PCL approached the Transportation Development Centre for help as it has been involved in various bus transportation projects including a market assessment for the Montreal/Quebec City Le Grand Express service to determine equipment requirements; an evaluation of the feasibility of higher capacity intercity buses in Canada; and a cooperative project with Voyageur Enterprises Ltd. to demonstrate articulated buses.

The approach in the study and the outline for this report was, with the support of a management consultant, to examine the existing system, define the problem, identify the options, recommend a course of action and, with the support of an engineering consultant, examine the feasibility of the preferred option.

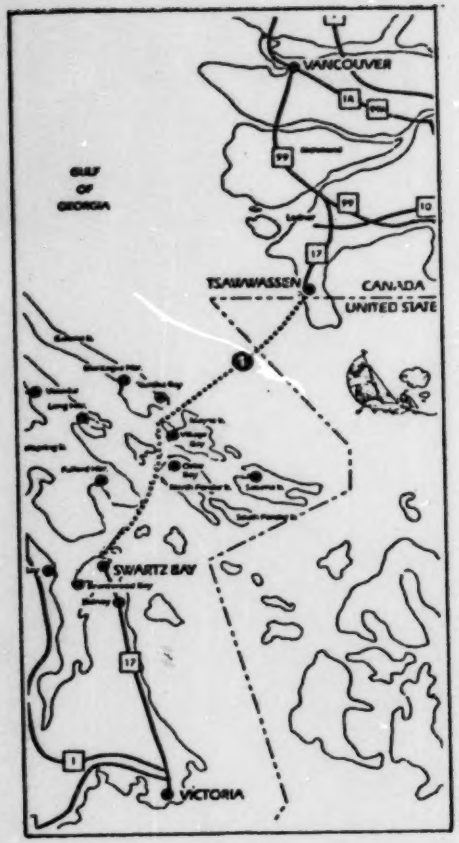


Figure 1 - PCL's Vancouver - Victoria Route

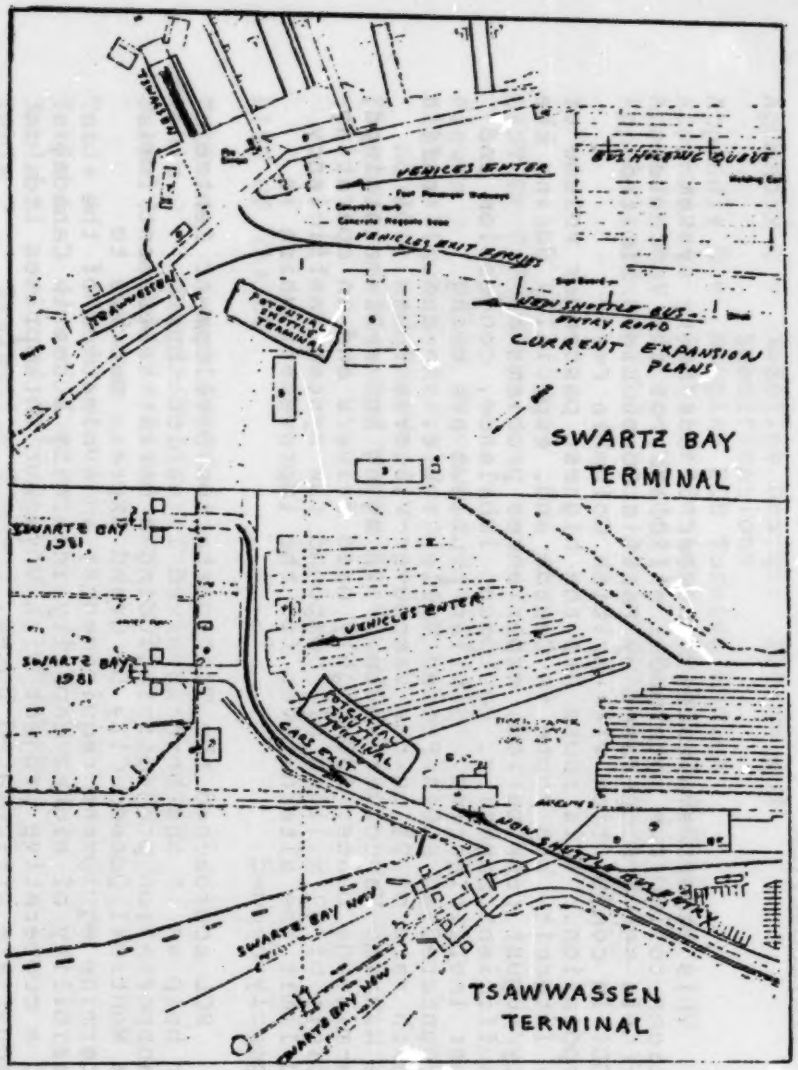


Figure 2 - B.C. Ferry Corp. Terminals, Swartz Bay and Tsawwassen

2. DESCRIPTION OF EXISTING SYSTEM

2.1 Route and Vehicle

The existing scheduled coach service between Vancouver and Victoria operates along the route described in Figure 1, using standard intercity coaches of approximately 45 seat capacity, with luggage compartments accessible from the outside. Coaches originating in Vancouver travel 32 km by road from a downtown depot to the Tsawwassen Ferry Terminal, where they board the ferry for a trip of one hour and forty minutes to the Swartz Bay Ferry Terminal on Vancouver Island. They disembark at that point and travel a further 32 km to the depot in downtown Victoria.

2.2 Ferry Terminals

At the ferry terminals, as shown in Figure 2, the coaches wait in a holding compound at the front of a queue of overheight vehicles and cars, while vehicles going in the opposite direction disembark. They then proceed onto the ferries, in position to be first off at the other end of the crossing.

2.3 Passenger Loading & Baggage

Passengers may join or leave the coaches at the downtown coach terminals, at various intermediate stops, or on the ferries. While on the ferries all passengers leave the coaches for passenger areas on upper decks. Those passengers travelling all the way between the downtown terminals place their luggage in the coach baggage compartments accessed from outside. Passengers boarding or departing at intermediate points must keep their baggage with them in the bus passenger compartment. In addition to the passenger baggage, the coaches also carry parcel express.

2.4 Coach and Ferry Schedules

Ferries leave from both sides of the water approximately every hour during the summer, and less frequently in the winter. To cover the road distance, pick up passengers at intermediate points, and board the ferries, coaches must leave the downtown terminals one hour before ferry departure. Coaches require about 35 minutes for the trip from the ferry to the downtown depots. The overall travel time is 3.5 hours from city centre to city centre. An example of coach schedules is shown in Table 1.

WESTBOUND BUSES

DEP. VAN.	ARR. TSAW.	ARR. SWARTZ	ARR. VICT.
6:00	6:45	8:55	9:30
7:00	7:45	9:55	10:30
8:00	8:45	10:55	11:30
9:00	9:45	11:55	12:30
10:00	10:45	12:55	13:30
11:00	11:45	13:55	14:30
12:00	12:45	14:55	15:30
13:00	13:45	15:55	16:30
14:00	14:45	16:55	17:30
15:00	15:45	17:55	18:30
16:00	16:45	18:55	19:30
17:00	17:45	19:55	20:30
18:00	18:45	20:55	21:30
19:00	19:45	21:55	22:30

EASTBOUND BUSES

DEP. VICT	ARRIV. SWARTZ	ARRIV. TSAW.	ARR. VAN.
6:00	6:45	8:55	9:30
7:00	7:45	9:55	10:30
8:00	8:45	10:55	11:30
9:00	9:45	11:55	12:30
10:00	10:45	12:55	13:30
11:00	11:45	13:55	14:30
12:00	12:45	14:55	15:30
13:00	13:45	15:55	16:30
14:00	14:45	16:55	17:30
15:00	15:45	17:55	18:30
16:00	16:45	18:55	19:30
17:00	17:45	19:55	20:30
18:00	18:45	20:55	21:30
19:00	19:45	21:55	22:30
20:00	20:45	22:55	23:30

Table 1 - Coach Schedule, Summer

NOTE: This schedule is slightly simplified from actual schedule in order to simplify comparative vehicle assignments.

2.5 Passenger and Bus Volumes

The number of buses on each coach departure is matched closely to the passenger demand, and varies considerably by time of year, day of week, time of day, and direction of travel. The variations are illustrated in Figure 3. Table 2 indicates hourly coach departures by day of week for the peak August period, and for a week in April that is typical of the off-season months from September to June. For the August week shown, the number of coaches per departure is now averaging six in the rush hours, and as high as seven or eight on busy days.

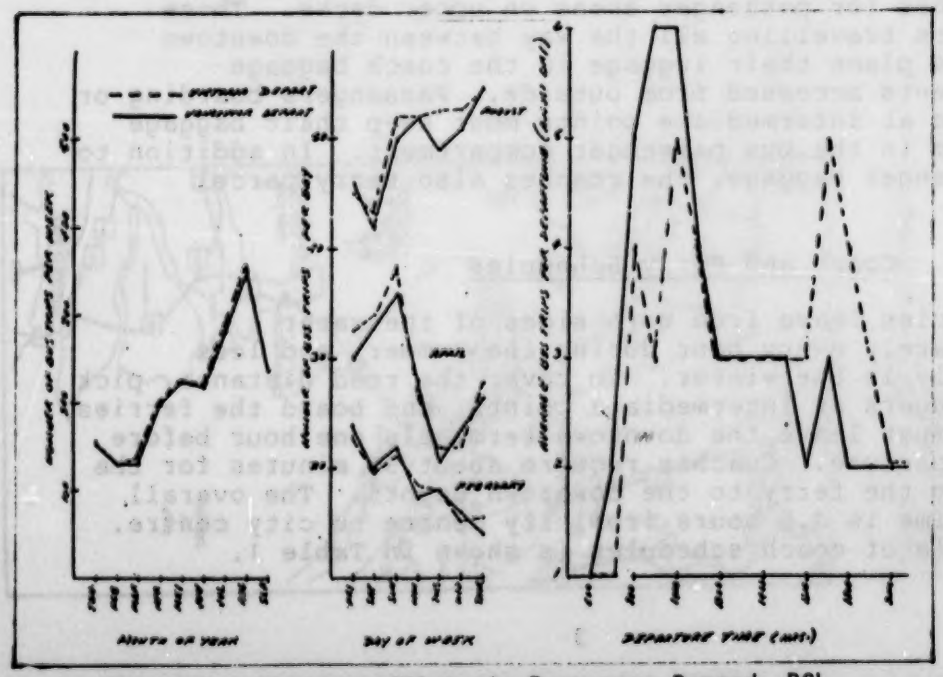


Figure 3 - Vancouver/Victoria Passenger Demand, PCL

2.6 Ferry Capacity

Ferry capacity for handling PCL coaches is determined both by physical constraints and B.C. Ferry Corporation policy. The vessels themselves have space for a mix of cars and overheight vehicles, depending on the particular ferry design. The overheight space on most of the Vancouver to Victoria ferries is capable of accommodating about 20 vehicles.* This space must be shared by PCL, tour coaches, commercial vehicles and campers. B.C. Ferry Corporation attempts to allocate the limited space in an equitable fashion depending on relative demands. Tour coaches must reserve, but no penalty exists for "no-shows". PCL is allocated five spaces per ferry departure although this is frequently exceeded.

April 5 - 11, 1980

Depart Vancouver									Depart Victoria								
Time	S	S	M	T	W	T	F	AV.	S	S	M	T	W	T	F	AV.
600	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1
800	4	2	3	4	2	2	4	3	2	1	1	1	1	1	1	1
900	3	2	1	2	2	3	2	2	3	2	3	3	2	3	3	3
1000	4	2	3	3	3	3	2	3	5	2	4	4	3	3	4	4
1200	4	3	5	3	3	3	3	3	2	2	3	1	1	2	1	2
1300	2	3	3	2	1	1	2	2	4	4	4	2	3	2	2	3
1400	2	3	4	3	3	3	2	3	3	5	6	4	3	2	3	4
1600	3	4	6	3	2	3	3	3	2	3	2	2	2	2	2	2
1700	1	3	3	2	1	2	2	2	3	5	5	3	2	2	3	3
1800	3	3	2	2	1	1	3	2	3	4	4	3	2	2	4	3
2000	2	4	4	1	1	1	2	2	3	2	2	1	1	1	2	2
2100	1	3	1	1	1	1	1	1	2	3	3	2	1	1	2	2
								27								30

August 2 - 8, 1980

Depart Vancouver									Depart Victoria								
Time	S	S	M	T	W	T	F	AV.	S	S	M	T	W	T	F	AV.
600	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1
700	3	2	2	3	2	3	2	2	2	1	1	1	1	2	2	1
800	6	3	4	5	6	5	4	5	4	3	3	3	4	4	4	4
900	5	5	4	6	6	6	7	6	3	2	2	4	3	3	4	3
1000	5	5	4	7	8	7	7	6	4	4	5	7	5	5	5	5
1100	3	5	4	5	4	5	4	4	3	3	4	4	4	5	4	4
1200	2	3	3	4	4	4	2	3	4	2	3	3	4	4	3	3
1300	4	3	4	3	4	2	3	3	3	3	4	4	3	2	4	3
1400	3	2	3	3	3	3	4	3	3	2	3	4	2	2	4	3
1500	3	3	3	3	2	2	3	3	1	4	4	3	3	3	3	3
1600	2	3	2	3	2	2	2	2	2	3	3	3	5	3	5	3
1700	3	2	3	3	2	3	3	3	5	4	5	4	5	6	6	5
1800	2	2	3	2	1	2	3	2	3	4	6	4	4	5	4	4
1900	2	1	3	1	1	1	2	2	2	3	3	3	4	4	3	3
2000	1	1	3	1	1	2	4	2	2	2	3	3	3	2	2	2
2100	1	1	4	2	2	3	4	2	2	2	2	1	2	2	1	2
								45								45

Table 2 Sample Vehicle Trip Records, 1980

* Since this analysis B.C. Ferry Corp. has added new vessels and modified to provide more overheight capacity. However this has not fully alleviated the overheight vehicle space limitations in the peak periods.

3. DEFINITION OF THE PROBLEM

For most of the year, the existing bus/ferry system operates quite efficiently, providing a convenient service for passengers and their baggage. During the two peak months of July and August, however, the ferry capacity is strained by high volumes of cars and overheight vehicles of all types. With scheduled coach passenger demands increasing at an estimated 10 to 12 per cent per year, the problem is likely to grow more acute. The challenge is to develop a means of increasing the passenger capacity without adding an overly burdensome capital expenditure to cover this short peak period. Potential solutions involve increasing the overheight capacity of the ferries themselves and better utilization of the space provided by PCL. During 1981, revisions to the schedules and change of ferry equipment sailing on the Tsawwassen to Swartz Bay route has increased capacity somewhat. This report, however, refers to means of better utilizing the overheight space provided.

4. DESCRIPTION OF ALTERNATIVE SERVICE OPTIONS

4.1 Option A

This is the existing system with standard coaches described in section 2.

4.2 Option B - Full Shuttle

This option would involve a shuttle service between the city centre depots and the ferry terminals. Passengers would get off the buses at the ferry terminals, walk onto the ferries, and then walk off the ferries at the opposite end to waiting buses. This would require a reallocation of the ferry terminal layouts to provide a drop-off and pick-up point close to the ferries and perhaps a new shuttle bus entry road to avoid having buses cross the path of cars entering and exiting the ferries. The bus drop off point would require space for as many as seven buses to first unload and then wait for passengers disembarking from the ferry. It would be inconvenient for passengers to carry their bags on and off the ferries, and therefore, baggage "pups" would likely be necessary. These could be unhitched from the buses and towed on and off the ferries by a tractor. For passengers not travelling all the way between the town terminals, the inconvenience of carrying their bags would be unavoidable, and they would not be able to leave them on a bus as at present. This procedure would result in a major imbalance of equipment for the operator due to the directional nature of the peak loads and would require considerable dead head mileage and surplus equipment.

4.3 Option C - Semi-Shuttle

This option would involve running at least half the coaches on each departure as a through service as at present. The remaining coaches would operate as shuttles, with passengers travelling the full distance placing their bags in the through coaches. The through coaches would also be used to pick up and drop off passengers not going the full distance. This would overcome some of the baggage handling difficulties of the full shuttle system, but could cause some confusion among passengers at the downtown depots over which bus to board, and which to retrieve their bags from at the opposite end. The system would also require a pick-up and drop-off point in the ferry terminal area, but only for three or four buses.

4.4 Option D - Double-Deckers

This option would involve replacing the entire Victoria-Vancouver fleet of standard coaches, with high capacity intercity double-deck buses.* For this analysis, it has been assumed that the double-deck buses could provide approximately 50% greater passenger capacity, with seats removed on the lower deck for storing baggage. With this modification, the system would operate the same as the existing system, with coach departures reduced by a ratio of two for three.

4.5 Option E - Mixed Fleet

This option would involve operating a mixed fleet of standard and double-deck buses. In the trip assignment analysis of section 5.2 below, it was found that 13 of the 25 double-deckers required to operate Option D would be required for almost 10 months of the year. Due to the high capital cost of the double-deckers, it is necessary to utilize them to their maximum potential. In this option during the off-season, the service would be operated almost entirely with double-deckers. During the peak season, the operation would change, with standard buses covering the base period, and the limited number of double-deckers operating only at the peak hours to meet the capacity problems on the ferries, the latter equipment being the lead coach.

* PCL has indicated that double-deckers would be deployed on the Fraser Valley and Vancouver Island routes as well.

5. EVALUATION OF ALTERNATIVES

5.1 Trip Volumes

The average daily coach trip departure volumes for August and April from Vancouver and Victoria shown in Table 2, were used for all the vehicle assignment calculations described in the following section.

5.2 Trip Assignment

Vehicles assignments for the existing and alternative options are shown in Appendix A. In these tables according to the schedules of Table 2, through-coach trips leaving either city centre depot would arrive at the other centre 3.5 hours later, ready to take the next trip out in the reverse direction .5 hours later. In the shuttle system, coaches leaving the depots would arrive at the ferry terminal within the hour, ready to take a coach load of passengers coming from the ferry, or deadhead back on the hour. The full shuttle round trip would be two hours. Passenger loads outbound from Vancouver Depot on the shuttle would show up as outbound coach trips from Swartz Bay 3 hours later and similarly coach loads departing Victoria would leave Tsawwassen 3 hours later for Vancouver.

The net column in the assignment tables represents the total number of coaches out of the city depots at any one time (shown as a minus). The highest negative value of net departures shown circled is the number of coaches required to run the system from that end.

The net column at the ferry terminals when positive, represents bus layovers, waiting for passengers from the next ferry, rather than deadhead back. In many cases, shuttle coaches taking passengers out to the ferries would have to wait an excessive time for a load of passengers from an incoming ferry. In these cases, they have been deadheaded back as indicated by the numbers in brackets.

The totals at the bottom of the trip assignment pages represent the numbers of trips. Vehicle requirements and trip volumes are summarized in Table 3. The existing system requires the most vehicles (37) not including spares. Option D requires the least number of vehicles (25) but greater cost. A significant point to notice in Table 3 is the considerable amount of deadheading and layover time required for the full shuttle, and semi-shuttle systems, due to the unbalanced nature of the loads from either direction.

The August Day and April Day figures have been converted to annual totals using factors described in Table 3.

	Vehicle Requirements			One - Way Trips				Layover Hours
	Full Trips	Shuttle Trips	Total	Full Trips	Shuttle Trips Pass	Deadhead	Total	
August Day								
A. Existing System Std.	37	-	37	98	-	-	-	0
B. Full Shuttle Std.	-	27	27	-	196	44	240	5
C. Semi Shuttle Std.	20	12	32	58	80	22	102	1
D. Double-Deckers	25	-	25	69	-	-	-	0
E. Mixed Fleet								
Double Deckers	13	-	13	26	-	-	-	0
Standard Buses	20	-	20	58	-	-	-	0
Total	33	-	33	84	-	-	-	0
April Day								
A. Existing System Std.	19	-	19	57	-	-	-	0
B. Full Shuttle Std.	-	14	14	-	114	20	134	26
C. Semi-Shuttle td.	11	6	17	35	44	8	52	10
D. Double-Deckers	13	-	13	42	-	-	-	0
E. Mixed Fleet								
Double Deckers	13	-	13	42	-	-	-	0
Standard Buses	0	-	0	0	-	-	-	0
Total	13	-	13	42	-	-	-	
Annual Operations								
A. Existing System Std.	Notes: Peak Season Trips			21660	-	-	-	0
B. Full Shuttle Std.	July and August			-	43320	8148	51468	7617
C. Semi-Shuttle Std.	= 57 X August Day			13176	16968	3510	20478	2877
D. Double-Deckers				15777	-	-	-	-
E. Mixed Fleet	Off-Season Trips							
Double-Deckers	September to June			13326				
Standard Buses	= 282 X April Day			3306				
				16632				

Table 3 Vehicle Fleet Requirements and Trip Volumes

5.3 Capacity

All of the alternatives examined require less ferry capacity than the existing system. As seen in the assignment tables, for the August Day loadings described, the existing system requires space for six buses. The shuttle system requires no bus space, but baggage "pups" would use up about two or three bus equivalents. The semi-shuttle option requires space for three buses, and the double-decker and mixed fleet options require space for four buses, a 50% improvement over the existing system.

5.4 Hourly Related Costs

The operating costs have been broken down into hourly related costs and distance related costs, with administrative costs pro-rated at 15% of each. The hourly costs include drivers' wages and benefits and supervisory personnel. A cost of $22 per scheduled hour is intended to include booking-in time, shift premiums etc., and is given in 1981 dollars. Scheduled hours are calculated by multiplying time per trip by the numbers of trips shown in Table 4. The existing system has the highest hourly costs of $1.9 million per annum, while the full shuttle is the lowest at $1.3 million.

	Annual Scheduled Driver Time (Hours)				Annual Hourly Cost ($000)
	Full Trips	Shuttle Trips	Layover Time	Total	
A. Existing System	86640	-	-	86640	$1906
B. Full Shuttle	-	51468	7617	59085	$1300
C. Semi-Shuttle	52704	20478	2877	76059	$1673
D. Double Decker	63108	-	0	63108	$1388
E. Mixed Fleet	66528	-	0	66528	$1464

Notes: Full one way trip time Van./Vict./Van. = 3.5 hours + .5 hours recovery = 4 hours
Shuttle one way trip Van./Tsaw. or Vict./Swartz = .7 hours + .3 = 1 hour
Hourly cost = $10.63 wage X 1.3 ben. X 1.15 admin. X 1.1 infl. X 1.25 unscheduled time
= $22 per scheduled driver hour

Table 4 Annual Hourly Costs

5.5 Distance Related Costs

These costs cover items related to distance travelled, such as fuel and maintenance. The cost for standard buses is taken as 35¢/km and is assumed to be 20% higher for double-deck buses at 42¢/km. The results shown in Table 5 show the full shuttle as having the highest cost at $ .58 million and the mixed fleet the lowest at $ .40 million.

5.6 Toll Costs

These are the charges of the B.C. Ferry Corporation for carrying the buses. A figure of $29 per coach trip for 1981 has been assumed. The full shuttle has no cost for this and the existing system, which has the largest volume of vehicles crossing, has the highest cost. The results are summarized in Table 5.

5.7 Annual Vehicle Costs

The vehicle costs are summarized in Table 6. Fleet size does not include replacements. Unit costs are based on approximate replacement costs. The annual amortization of

	ANNUAL VEHICLE KM. (000) FULL KM	SHUTTLE KM.	TOTAL KM.	ANNUAL DISTANCE COST $(000)	ANNUAL TOLL COST $(000)
A. Existing System	1,386	-	1,386	$ 485	$ 628
B. Full Shuttle	-	1,647	1,647	$ 576	-
C. Semi-Shuttle	843	655	1,498	$ 524	$ 382
D. Double-Decker	1,010	-	1,010	$ 424	$ 457
E. Mixed Fleet					
Double Decker	853	-	853	$ 328	
Standard	212	-	212	$ 74	
				$ 402	$ 482

Notes: Travel Distance full trips = 64 km.
Travel Distance Shuttle Trips = 32 km.
Distance Cost = ($5.60 fuel + $5.37 tire + $5.48 maintenance + $1.09 insurance) = $17.45 per trip ($1980)
Distance Cost Total ($1981) = $17.54 X $1.15 administration X $1.1 inflation = $22.18 ÷ 64 = 35¢/km.
Distance Cost Double Deckers = 1.2 X Dist. Cost Standard Buses = 1.2 x 35¢ = = 42¢/km.
Toll Cost = ($1981) = $29 per ferry trip.

Table 5 Annual Distance and Toll Costs

		Venicles Regd.	Unit Cost ($000)	Total Cap. Cost ($000)	Annual Amort. Cost ($000)
A. Existing System		37	150	5550	482
B. Full Shuttle		27	150	4050	352
C. Semi-Shuttle		32	150	4800	417
D. Double Decker		25	400	10000	868
E. Mixed Fleet	D.D	13	400	5200	
	Std.	20	150	3000	
	Total	33		8200	618

Notes: Costs assume full replacement ($1981) for comparative purposes
Annual amortization costs based on 15 year life 3.5% real interest cost (cap. recovery factor .08683)

Table 6 Annual Vehicle Costs (Approx)

vehicle costs is based on real interest rates of 3.5% (the difference between money interest rates and the rate of inflation). The costs for the full shuttle system do not include baggage pups, and therefore, understate the total. No cost has been estimated for yards and shops for any of the options.

5.8 Terminal Costs

No costs have been estimated for terminal facilities at the town depots or at the ferry terminals. The full shuttle would have the highest costs in this category and the semi-shuttle system would have the next highest costs. The other systems would not have any new costs, but clearance heights of the double-deckers still remain to be checked.

5.9 Passenger Convenience and Baggage Handling

The existing system and the two double-decker options are equally convenient for passengers and their luggage. The full shuttle system would be the least convenient even with baggage "pups" and drop-off terminals close to the ferry berths. Passengers not going all the way would still have to carry their bags and look after them on the ferry. The semi-shuttle would be more convenient in this regard but might still involve some confusion.

5.10 Reliability and Scheduling

The existing system, depending on traffic conditions, is scheduled fairly tightly. With the double-deckers, speeds and highway performance should be further investigated to see if these schedules can be maintained, but generally there should be no problem. For the shuttle systems, the trip assignments and costs are based on a very tight schedule that might not be possible to maintain. Adding 15 minutes to the scheduled shuttle times would increase vehicle requirements and costs.

6. RECOMMENDED COURSE OF ACTION

Table 7 below summarizes the comparison of options A-E.

	Option A Existing System	Option B Full Shuttle	Option C Semi Shuttle	Option D Double Decker	Option E Mixed Fleet
Annual Hourly Cost	1906	1300	1673	1388	1464
Annual Distance Cost	485	576	524	424	402
Annual Toll Cost	628	0	382	457	482
Annual Veh. Cost	482	352	417	868	618
Sub Total Operating	3501	2228	2996	3137	2966
Baggage "Pup" Cost	0	+	0	0	0
Yard and Shop Cost	?	?	?	?	?
Terminal Cost		++	+		
Capacity	Worst	Best	Good	Good	Good
Passenger Convenience	Good	Poor	Fair	Good	Good
Reliability	Good	Poor	Fair	Good ?	Good ?

* All costs in ($000)

Table 7 Evaluation Summary

A full shuttle system option B, with no buses, and only baggage "pups" going on board the ferries would provide the best solution to the capacity problem, and would have the lowest direct bus system operating costs. These cost advantages would be eroded to some extent when the cost of baggage "pups", and the cost of pick-up, drop-off terminals are included. Even with these facilities, this system, while technically feasible, would be the least convenient for passengers and their luggage, and would present difficult scheduling problems for the operator.

A semi-shuttle system, Option C, with half the coaches operating as shuttles, and the remainder carrying the luggage boarding the ferries for the full journey, would alleviate some of the passenger convenience problems, and improve the capacity problem that now exists. After adding in terminal costs, it would likely cost as much as the existing system, and would present additional customer confusion and operator scheduling problems.

A system operating as at present with a full fleet of double-deck buses, Option D, would give all the convenience of the exisiting system, and perhaps at lower cost in the long run. It would also add about 50% to the passenger capacity of the system.

A mixed fleet of double-deckers and standard buses, Option E, may be the best overall solution. Using a limited fleet (about 13 double-deckers) operating full time to provide the base off-season service, and then switching them to provide only peaking capacity in the rush hours of the peak season, with the base service provided by standard buses (the latter equipment being the lead coach), would be an ideal application for high cost, high capacity buses. The short length of double-deckers would make them more appropriate than articulated vehicles for the capacity problems of the ferry system. This system would have all the convenience features of the existing system, and based on the preliminary costing appears to be the second least expensive system to operate, and may be the least expensive overall with all costs calculated. Based on this assessment, this option is recommended.

Availability of suitable double-deck buses presents several problems: no such equipment is currently available in Canada and non-Canadian double-deck buses are expensive. Modifications required to make imported bus equipment acceptable in North America increases the already high price.

It was decided to investigate the feasibility of building a Canadian double-deck bus as carrier demand could be a major stimulus to such development.

7. FEASIBILITY OF A CANADIAN-BUILT DOUBLE-DECK BUS (DDB)

The primary object of section 7 is to investigate the constraining parameters which define such a vehicle, and to establish a baseline design. The most critical parameter is height, since the vehicle must respect the British Columbia road clearance height of 4.12 m (13.5 ft) due to existing bridges and tunnels.

Two West German firms build large capacity intercity DDBs and one of them (NEOPLAN) has established a plant in Lamar, Colorado. They offer their Skyliner, the dimensions of which are 12 m x 2.5 m x 4 m (39.37 ft x 8.2 ft x 13.1 ft) and which seats 72 passengers. It is fitted with a Detroit Diesel engine and an Allison transmission. This power train has been the most universally accepted for large buses in North America.

In the SKYLINER, the headroom is limited to 1.82 m (approx. 6 ft) on the lower deck and 1.69 m (5 ft 6½ in) on the upper deck. Since this is somewhat inconvenient the proposed baseline design should provide an improvement in this respect.

The double-deck configuration has very limited acceptance in North America, but this is probably because conventional double-deckers exceed normal US overhead clearance. A double-decker built within the 4.12 m (13 ft 6 in) limit would therefore be acceptable. This is viewed as timely for Canadian development. Although the articulated bus has been identified (1) (2) as being most suitable for development of large capacity buses, the DDB is perceived to have many advantages.

These include:

- particularly suitable to the intermodal service;
- easier to manoeuvre, particularly in reverse, and easier to park, (although not having a shorter turning radius than an "artic");
- requires less terminal (land) area;
- passenger appeal due to the view from the upper deck;
- optimization of road space (or deck space);
- less objectionable to other traffic due to shorter length, especially when passing;
- easier to pass other vehicles;
- relative mechanical simplicity, since there is no turntable;
- very suitable to mixed parcel/passenger loads.

In general, rising energy and labour costs render high capacity buses more efficient, the largest space envelope being most cost effective. The two principal candidates, the articulated bus and the double-deck bus, have been developed in Europe and are in service. The double-decker proposed herein is unique in that the vehicle is not excessive in height, but offers more interior headroom than competitive European equipment. The proposed baseline design seats 92 passengers.

7.1 Baseline Design Objectives

7.1.1 Since this is essentially a study of feasibility, the baseline design is intended to provide the simplest definition of a practical vehicle including consideration of at least the following:

- basic dimensions
- weight and centre of gravity
- performance
- structural concept
- suspension

7.1.2 The baseline design is intended to define a vehicle which could be built using state-of-the-art technology.

7.1.3 The principal major components are to be identified.

7.1.4 The baseline design is to be used as a datum, for on-going studies, when considering alternative configurations and advanced concepts.

7.1.5 A first approximation of unit cost and development cost to be included.

7.1.6 Within budgetary constraints, future trends to be examined, particularly with respect to energy conversion and "space-age" structural materials, as they affect weight and cost.

7.1.7 Concepts are to be proposed for the solution of those immediate problems which require the most innovation. The principal areas of consideration involve specifically:

- overall clearance and interior headroom
- structural concept
- drive lines
- suspensions

7.2 Baseline Design

7.2.1 Length

The point of departure for this design is a sketch of a double-deck bus prepared by B. Clark of Pacific Coach Lines as part of an Interim Report (3) to TDC upon the completion of the first part of the present study, carried out by Hickling-Partners Inc. The sketch is reproduced herein as Appendix B.

Mr. Clark refers to 35 ft, 40 ft and 45 ft as possible lengths for a family of vehicles, and on the sketch the vehicle is presented as being 13.7 m long (45 ft).

Quoting from a PCL memo of 17 Sept. 1980 to the PCL Board of Directors, from General Manager Mr. G.J. Thomas.

> "It would appear that there are no serious regulatory restrictions standing in the way of a potential introduction of high capacity buses of the double-deck variety. The current B.C. restriction of 41 feet length would require modification or exemption in the case of the articulated unit which is up to 60 ft long."

7.2.2 Turning Radius

The principal practical constraint on the vehicle length is the turning radius. The baseline design has a 14 m (46 ft) turning radius to the outside corner. (See drawing Appendix C turning radius diagram, and for comparison see the NEOPLAN diagram Appendix D. It is approximately equal to the overall length. The wheel-cut angle used is 45 degrees, which is about the maximum practical angle. The proposed Rockwell International front axle has a turning capability of up to 50 degrees. The "wall-to-wall" diameter of the turning circle is 28 m (92 ft), which is considered acceptable. It would be possible to make small improvements by shortening the wheelbase. It is not considered necessary to provide any steering of the rear axle. (This is possible, but would require special design of the rear bogie). Suitable drive steer axles would be expensive and may be unavailable.

It is evident that reducing overall length, say to the legal limit of 41 ft would make possible proportionate reductions of wheelbase, and therefore of turning radius, with a corresponding reduction in the number of seated passengers.

The length of the rear overhang is limited by law to 3.048 m (10 ft). To keep within this dimension with a longitudinal engine layout the baseline design utilizes a novel drive-line layout. The engine is placed off-centre with the drive-line passing over the two rear axles into a "nose-box", which is a transfer case arranged to drive from ahead of the axles. Most GMC buses use transverse engines and transmissions and axles with V-drive. An Allison transmission with V-drive is available, but not with the torque capacity desired in this case. Therefore to avoid a special V-drive development, an in-line drive is preferred, this also offers the potential of improved fuel economy due to the reduced frictional loss inherent with an in-line drive.

7.2.3 Width

A width of 2.59 m (102 in) is legal throughout Canada, whereas in the United States, 96 in is the predominant legal width, with some 18 states approving 102 in. The usual legal width in Europe is 2.5 m (98.4 in).

The baseline design is shown (Appendix C) with a width of 102 in (2.59 m). There are some potential benefits to greater width. A thicker side structure may be used, which is desirable in view of the thin floors (see section 7.2.10). Also space between wheel arches, for stairways and for baggage capacity could all be optimized. But there is no corresponding increase in stability unless wider axles are available, none being known at this time; however this problem would be obviated if suitable IFS/IRS units were developed.

A comment in reference (1) (p. 1-2) is worth noting: "One of the reasons that a 102 in wide bus never gained a significant market was that it in fact decreased driver productivity because of the unit's higher per seat cost."

7.2.4 Height

In British Columbia and all provinces except two, the legal maximum vehicle height is 13 ft 6 in (4.44 m). In Ontario it is 13 ft 7⅝ in (4.15 m) and in Prince Edward Island it is 14.5 ft (4.42 m). In the baseline design an effort has been made to maintain "full" headroom in both decks. The dimension selected is 74 in (1.88 m) which will accommodate the 95th percentile male and 99th percentile female passenger. (ref (4) p. 99).

For comparison, the British "Standard High Bridge" type DDB is 14 ft 4 in (4.37 m) high, (unladen) and has headroom

heights of 5 ft 10¼ in (1.78 m) and 5 ft 8½ in (1.74 m) on the lower and upper decks respectively, Reference (4) (p. 98). The "Standard Low Bridge" design, is 13 ft 5½ in (4.1 m) (unladen), with the upper deck having a side aisle, with headroom as before, except over the lower deck seats under the upper aisle.

As mentioned earlier the NEOPLAN SKYLINER has 1.82 m (6 ft approx.) on the lower deck and only 1.69 m (5 ft 6.5 in) on the upper deck.

The proposed headroom of 1.88 m (74 in) leaves 0.356 m (14 in) altogether for underbody clearance and structure. An underbody clearance of 0.254 m (10 in) will leave 102 mm for structure or about 34 mm (1.3 in) for each of roof, upper deck aisle and lower deck aisle. Obviously, this will create special design conditions which require careful conceptual and analytical attention.

In the proposed arrangement (Appendix C) the front floor is raised to accommodate suspension, axles, and steering, and as well, to make feasible the 10 degree approach angle which is believed to be a practical minimum for crossing ramp thresholds, such as are found at ferry boarding ramps, garages, railway crossings, and the like. To maintain headroom over this raised portion of the lower deck means a sacrifice of headroom at the front of the upper deck, where the headroom is reduced to 1.66 m (5 ft 5.25 in) affecting five rows of seats.

Increased floor height over the rear axle bogie is required for the differentials, suspensions, and drive-lines; however, the baggage compartment does not require headroom, (although the rear of the upper deck could be treated similarly to the front, raising it to provide more baggage space and less upper deck headroom). The baggage compartment extends from ahead of the rear bogie to the rear of the bus with diminished headroom in this whole area.

7.2.5 Vehicle Configuration

Having now established the basic dimensions it is necessary to undertake an iterative process involving vehicle weight estimate, selection of appropriate major components, such as axles, wheels and tires, engine, transmission and driveline layout. This process culminates in the design presented as Appendix C.

7.2.6 Weight and Balance

Appendix (E) shows the preliminary Weight and Balance. It will be seen that the estimated weight of the vehicle is 25196 kg (55547 lbs) with 92 passengers, driver, and 363 litres (80 Imp. Gal) of diesel fuel (the baseline design does permit a greater fuel capacity). The weight distribution is 9960 kg (21957 lbs) on the front bogie (39.5%) and 15236 kg (33590 lbs) or 60.5% on the rear bogie.

7.2.7 Tires

The tire selected is 9.00 R 20 - 14 PR which has a capacity at highway speeds of:

- single - 2499 kg (5510 lbs)
- dual - 2304 kg (5080 lbs)

It is chosen primarily for its combination of compact dimension, load capacity, and general availability. It is approximately 40 in in diameter (1.02 m).

Duals are used on the rear bogie, and singles on the front axles.

The 20 in wheel is the smallest which can be accommodated on the selected axles, and can be fitted over the Stopmaster drum brake.

The use of the smallest possible diameter wheels is essential, to compatibility with the low floor. Even though the floor at the front is raised over the axle area, it is desirable to fit lateral facing seats over the wheel arches, and sufficient headroom must be provided over them. This is achieved quite satisfactorily with the proposed design (see Appendix C). A larger wheel would absorb more space since the wheel arch would increase in height, length and width, although a 10.00 R 20 could probably be accommodated. It will be clear from the Weight and Balance why two front steering axles are required. A 9979 kg (22000 lb) single front axle, or alternatively, independent wheel suspension units would have dimensions incompatible with the floor height and headroom required for the DDB. A single axle, if one could be found having 9979 kg (22000 lb) would require single tires, having twice the capacity of the 9.00 R 20 selection. A suitable choice would be the 18. - 22.5 tire, which has a 10000 lb (4538 kg) capacity, but is 45.3 in diameter (1150 mm), an increase of 5.2 in (132 mm), and is twice the width, 18 in (457 mm).

For these reasons the 9.00 R 20 tire used on two steering axles, which are readily available, represent a satisfactory solution.

A final constraint on wheel size is the requirement that, with a flat tire, the wheel rim be still large enough so that no part of the fixed axle should touch the ground. The rim radius is 254 mm (10 in) and the rim flange height is 38.1 mm (1.5 in), for a total of 292.1 mm (11.5 in). The axle centre drop is 88.9 mm (3.50 in) and the depth of beam is 123.4 mm (4.86 in) for a total of 212.3 mm (8.36 in). Therefore the minimum clearance under the beam with flat tires is in excess of 76 mm (3 in), which is acceptable.

7.2.8 Axles and Suspensions

At the outset of this study it was considered that the low floor of the DDB would almost certainly lead to the use of Independent Front Suspension (IFS) and possibly Independent Rear Suspension (IRS).

It was also realized that IFS and IRS components are not marketed normally for general use. In Europe and in North America they are proprietary designs of the vehicle or chassis builder. They offer the inherent potential of improved ride quality, since movements of one wheel do not impose a sympathetic response on any other.

Also, the concept of IRS using trailing rather than lateral arms can maintain axles in a horizontal attitude with only vertical deflection, so that the roll resistance is effectively at the tire centre rather than inboard at the spring. This of course can be used to enhance stability, a great virtue in a DDB with relatively high centre of gravity.

The difficulty is that such designs require special development, involving design, prototyping, testing and tooling, together with the disadvantage of relatively low volume costs. In spite of this it may well be argued that if there is a large international market to amortize the costs, it is justifiable since a tangible improvement in ride may be expected. Nevertheless independent suspensions are relatively rare in large vehicles, the ride quality with rigid axles being quite acceptable, perhaps because of generally good roads.

The final choice between rigid axles and independent suspension is beyond the scope of this study. Both systems can make a strong case for their merits. The choice of

rigid axles for present purposes is logical since this is a study of feasibility and a final selection is not necessary.

Rigid axles will serve equally well as a starting point for a study of IRS or IFS since the major components, differentials, hubs, gears etc., could be carried over from the rigid axles.

Front Axles (2): The axle selected is the Rockwell International FF-931 series drop centre forged steel axle of 4990 kg (11000 lbs) capacity. Aluminum hubs and Stopmaster air brakes (drum type) are available. The "Stopmaster" brake is smaller in diameter and lighter than the alternative "Cam-master".*

Rear Axles (2): The axles selected are Rockwell International SQHP single reduction tandem axles, with Stopmaster drum brakes, aluminum hubs. To provide adequate traction two driving axles are necessary in a vehicle of this GVW, rather than a single driving axle with a "tag" (non-driving axle). The SQHP has hypoid gears in the "front" single reduction axle, and amboid gears in the "rear" axle. The amboid design has the input pinion centre-line above the axle centre, thus lending to a shorter inter-axle drive shaft with less angularity.

The rigid axles, being of U.S. manufacture, are planned not to exceed 96 in in width, (2.44 m). If the vehicle is built for U.S. service, this is a mandatory requirement. Here we can perceive an advantage of IFS and IRS since it should be possible to build them in appropriate track to suit 96 in (244 m), 98.4 in (2.5 m) or 102 in (2.59 m) widths as required, and use the greater width to enhance stability. The cost of developing these components, however, may be prohibitive.

Suspension Systems: The suspensions must impart to the vehicle body both acceptable ride quality and adequate stability. Various media for energy absorption present themselves, including steel coil springs, air springs and air/oil or gas/oil systems. Leaf springs are not included because their spacing, at the front axles, is relatively narrow, (approx. 40 in (1.02 m)) while with other systems up to 60 in (1.54 m) is attainable representing up to 50% improvement in stability. In the present configuration MacPherson struts (coil springs with shock absorbers), or

* Note: Brochures on this hardware and most of the hardware described in this report are contained in the original report received from Hovey & Associates and now located in the TDC library (TL/232/W27).

air springs adapt well in principle, but the design of the drop centre axle presents some difficulty since the springs must be placed up on the shoulders of the axle beam. Air springs of the rolling-lobe type are widely used in buses and share with oil/gas systems the advantage of maintaining uniform height under load.

This leads to the idea of Active Ride Control. Here hydraulic cylinders adjust height in response to levelling valves which respond to load changes, but the springing medium is a gas accumulator, whose design is tailored to the required spring rate characteristics. An inertial system prevents height changes due to road shocks. This system also lends itself to gravitationally sensitive control which would allow the coach to "lean" into corners thereby improving stability and passenger comfort.

Torque rods and panhard rods with spherical bushings are used to position the axles.

7.2.9 Engine, Transmission and Performance

The engine selected is the Detroit Diesel 8V92T. It is rated 430 hp @ 2100 rpm and is remarkable for its short length. This is of fundamental importance since the engine must be placed longitudinally in the rear overhang.

There is a smaller engine of the same family, the 6V92T which is rated 335 hp @ 2100 rpm. The performance of the baseline design would be inadequate with this engine. For example, at 105 kph (65 mph) the gradeability with 8V92T engine is 0.9%. With the 6V92T engine, it is unable to achieve 105 kph, but has a gradeability of 0.7% at 80 kph (55 mph). The automatic transmission selected to use with the 8V92T engine is the Detroit Diesel Allison HT740D. This transmission has the required torque and speed capability. It is not available in a V-drive configuration such as is used in many General Motors buses with transverse engines.

7.2.10 Structural Concept (ref. Appendix C)

The special overhead clearance and headroom requirements are unusual and require a novel structure. Up until relatively recently British double-deckers would have a body unit mounted upon a chassis to which the engine, transmission and axles were also mounted. The chassis would be relatively flexible by virtue of its rather shallow dimensions, as compared to the very deep body which by its nature is stiff. The body therefore had to support itself, and relate to the chassis through flexible mountings.

The drive to reduce weight and cost resulted in semi-monocoque construction in which there is no separate chassis as such. The body is designed to carry itself as before. It has crossmembers to support floor loads, which are thus carried into the sides of the body. The sides act as longitudinal girders, and are reinforced to take the loads at the points where the suspensions are connected. Longitudinal chassis members are not necessarily continuous. In another concept, tank trailers are often built with no chassis, being essentially a tube with intermittent bulkheads and short sills at the fifth wheel and bogie support points.

In the baseline design there is room for principal crossmembers under the floor only in the areas over the suspensions where the floor has been raised for this (and other) purposes.

A main bolster is placed at the centre of each pair of axles, front and rear. Directly above each of these bolsters is a ring-type bulkhead which is integral with the body.

These two principal bulkheads are joined front-to-rear by the body side panels, which may be considered to be longitudinal side girders. Their ribs are made deeper than those found on conventional bus bodies, resulting in a thicker structure. Cantilever ribs integral with the body sides reach under the seats where the floor is higher than the aisles. These collect the seat and floor loads and transfer them to the body sides.

The aisles are formed of aluminum extruded hollow sections similar to the floors of transport trailers. These collect aisle floor loads and transmit them to the cantilever structures under the seats, to which they are integrally attached, by bolting or rivetting.

The roof, upper aisle, and lower aisle complete the tubular nature of the body shell, which being a closed structure is inherently stiff in torsion.

The wheelhouses and some auxiliary underfloor crossmembers at the front may be used as support structures to transfer weight to the front springs, which are located ahead of and behind the main bolster/bulkhead system.

In the baseline design, the body is conceived as mostly of aluminum extrusion, sheet and plate, of rivetted construction, with body ribs formed from sheet, much like an aircraft fuselage.

Use of more exotic materials such as Kevlar and carbon fibre may be used as necessary to solve unusual problems or to enhance body weight or strength. Such materials would normally be used only insofar as they are cost effective.

7.3 Future Trends

A number of SAE papers concerning future trends in bus construction and materials have been reviewed and abstracts are provided in Appendix F.*

7.4 Unit and Development Costs**

Engineering	Total Cost	$300,000.
Development		
Tooling		$500,000.
Prototype		$650,000.
	Sub-Total	$1,450,000.
Testing & Certification		$100,000.
Net Development Cost		$1,550,000.
Unit Cost:		
Material & Overhead		$232,415.
Labour & Overhead		35,400.
	Sub-Total	$267,815.
G & A 18%		48,207.
	Sub-Total	$316,021.
Profit 10%		31,602.
	Sub-Total	$347,624.
Warranty 3%		10,429.
Development amortized on 100 units		15,500.
FOB Factory		$373,553. (1981)
FST Extra		

Table 8 A Canadian Double-Deck Bus, Development and Unit Cost Estimates

* Hovey has since given consideration to a bus for the year 2000 and beyond. This is described in Appendix G.

** These cost estimates assume the engineering and prototype development are handled by an independent engineering company in conjunction with a manufacturer as opposed to a manufacturer solely.

7.5 Areas Requiring Major Design Effort

The principal areas requiring major design effort have been identified. They are the structural design, which is unique in concept due primarily to the conflicting requirements of headroom and limited overall height; the suspensions, which should be carefully designed to restrain vertical movement and provide stability consistent with the double-deck concept; and, the driveline arrangement requiring special dispositions. The engine is placed off-centre with the drive-line going forward over the axles to a nose case or transfer case on the forward tandem axle. This is required to keep the rear overhang within legal limits. No adequate angle drive transmission or axles are available.

8. CONCLUSIONS

8.1 An initial assessment of various options to improve the Vancouver-Victoria bus/ferry service, cost-effectively, resulted in the recommendation that PCL consider acquiring double-deck buses and, with standard buses, operate a mixed fleet.

8.2 There are two ways to acquire double-deckers: import and modify expensive non-Canadian equipment; or to have a double-deck bus built in Canada, if feasible.

8.3 The feasibility of building a Canadian DDB has been examined with the following conclusions:

8.3.1 A baseline design has been prepared and it is believed entirely possible using state-of-the-art techniques to build such a vehicle that will perform as calculated.

8.3.2 The baseline design successfully meets the requirements of overall height, width and turning radius and is within the Highway Traffic Regulations of all provinces of Canada, except for length. It also meets the dimensional limits of the United States except for width and length. There is no problem in building a vehicle to meet the existing length and width requirements.

8.3.3 The estimated development and unit costs have been estimated and are considered encouraging. The estimated development cost, is $1.55 million. The unit cost is estimated to be $374,000.

REFERENCES

(1) A Feasibility Study of the Introduction of Larger Capacity Intercity Buses, N.D. Lea & Associates Ltd.

(2) The Potential for High Capacity Buses in Canada, De Leuw Cather report dated March 1979, TP 1990.

(3) Interim Report by B. Clark of PCL to TDC.

(4) Project Super Bus: High Capacity Bus Conceptual Design Study, U.S. Department of Transportation PB 243693.

APPENDIX A
TRIP ASSIGNMENT TABLES
Trip Assignment A - Existing System

August Day

Time	Van. Depot Coaches In	Van. Depot Coaches Out	Van. Depot Coaches Net	Vict. Depot Coaches In	Vict. Depot Coaches Out	Vict. Depot Coaches Net
6:00		1	-1		1	-1
7:00		2	-3		1	-2
8:00		5	-8		4	-6
9:00		6	-14		3	-9
10:00	1	6	-19	1	5	-13
11:00	1	4	(-22)	2	4	(-15)
12:00	4	3	-21	5	3	-13
13:00	3	3	-21	6	3	-10
14:00	5	3	-19	6	3	-7
15:00	4	3	-18	4	3	-6
16:00	3	2	-17	3	3	-6
17:00	3	3	-17	3	5	-8
18:00	3	2	-16	3	4	-9
19:00	3	2	-15	3	3	-9
20:00	3	2	-14	2	2	-9
21:00	5	2	-11	3	2	-8
22:00	4		-7	2		-6
23:00	3		-4	2		-4
24:00	2		-2	2		-2
	2		0	2		0
TOTAL	49	49		49	49	

April Day

Time	Van. Depot Coaches In	Van. Depot Coaches Out	Van. Depot Coaches Net	Vict. Depot Coaches In	Vict. Depot Coaches Out	Vict. Depot Coaches Net
6:00		1	-1		1	-1
7:00						
8:00		3	-4		1	-2
9:00		2	-6		3	-5
10:00	1	3	-8	1	4	-8
11:00						
12:00	1	3	(-10)	3	2	-7
13:00	3	2	-9	2	3	-8
14:00	4	3	-8	3	4	(-9)
15:00						
16:00	2	3	-9	3	2	-8
17:00	3	2	-8	2	3	-9
18:00	4	2	-6	3	3	-9
19:00						
20:00	2	2	-6	3	2	-8
21:00	3	1	-4	2	2	-8
22:00	3		-1	2		-6
23:00						
24:00	2		+1	2		-4
	2		+3	1		-3
TOTAL	30	27		27	30	

Trip Assignment B - Full Shuttle
(August Day)

Time	Van. Depot Coaches In	Out	Net	Tsawwassen Coaches In	Out	Net	Vict. Depot Coaches In	Out	Net	Swartz Bay Coaches In	Out	Net
6:00		1	-1					1	-1			
7:00		2	-3	1	(1)	0		1	-2	1	(1)	0
8:00	(1)	5	-7	2	(2)	0	(1)	4	-5	1	(1)	0
9:00	(2)	6	-11	5	1(4)	0	(1)	3	-7	4	1(3)	0
10:00	1(4)	6	-12	6	1(5)	0	1(3)	5	-8	3	2	1
11:00	1(5)	4	-10	6	4(1)	1	1	4(1)	-12	5	5	1
12:00	4(1)	3	-8	4	3	2	4	3(3)	-14	4(1)	6	0
13:00	3	3(1)	-9	3	5	0	3	3(1)	-15	3(3)	6	0
14:00	5	3	-7	3(1)	4	0	5	3	-13	3(1)	4	0
15:00	4	3	-6	3	3	0	4	3	-12	3	3	0
16:00	3	2(1)	-6	3	3	0	3	3	-12	3	3	0
17:00	3	3	-6	2(1)	3	0	3	5	-14	3	3	0
18:00	3	2(1)	-6	3	3	0	3	4	-15	5	3(2)	0
19:00	3	2(3)	-8	2(1)	3	0	3(2)	3	-13	4	2(2)	0
20:00	3	2(2)	-9	2(3)	5	0	3(2)	2	-10	3	3	0
21:00	5	2(1)	-7	2(2)	4	0	5	2	-7	2	2	0
22:00	4	(2)	-5	2(1)	3	0	4	(2)	-5	2	2	0
23:00	3	(2)	-4	(2)	2	0	3	(2)	-4	(2)	2	0
24:00	2		-2	(2)	2	0	2		-2	(2)	2	0
	2		0				2		0			
TOTAL	49(13)	49(13)		49(13)	49(13)	3	49(9)	49(9)		49(9)	49(9)	2

196 (44)

Trip Assignment B - Full Shuttle
(April Day)

Time	Van. Depot Coaches In	Out	Net	Tsawwassen Coaches In	Out	Net	Vict. Depot Coaches In	Out	Net	Swartz Bay Coaches In	Out	Net
6:00		1	-1					1	-1			
				1						1		
7:00					(1)	0					(1)	0
	(1)						(1)					
8:00		3	-3					1	-1			
				3						1		
9:00		2	-5		1(2)	0		3	-4		1	0
	1(2)			2			1			3		
10:00		3	-5		(1)	1		4	-7		(2)	1
	(1)			3			(2)			4		
11:00			-4		1	3			-5		3	2
	1						3					
12:00		3(1)	(-7)		3	0		2(1)	-5		2	0
	3			3(1)			2			2(1)		
13:00		2	-6		4	0		3	-6		3	0
	4			2			3			3		
14:00		3	-5			2		4	(-7)		(2)	1
				3			(2)			4		
15:00					2	3			-5		3	2
	2						3					
16:00		3(1)	-7		3	0		2(1)	-5		2	0
	3			3(1)			2			2(1)		
17:00		2	-6		4	0		3	-6		3	0
	4			2			3			3		
18:00		2	-4			2		3	-6		(1)	2
				2			(1)			3		
19:00		(1)	-5		2	2			-5		3	2
	2			(1)			3					
20:00		2(1)	-6		3	0		2	-4		2	0
	3			2(1)			2			2		
21:00		1	-4		3	0		2	-4		2	0
	3			1			2			2		
22:00		(1)	-2			1			-2			2
				(1)								
23:00		(2)	-4		2	0		(1)	-3		2	0
	2			(2)			2			(1)		
24:00			-2		2	0			-1		1	0
	2		0				1		0			
TOTAL	30(4)	27(7)		27(7)	30(4)	14	27(6)	30(3)		30(3)	27(6)	12
						114 (20)						

TRIP ASSIGNMENT C - SEMI-SHUTTLE (FULL TRIPS)

	August Day						April Day					
	Van. Depot Coaches			Vict. Depot Coaches			Van. Depot Coaches			Vict. Depot Coaches		
Time	In	Out	Net	In	Out	Net	In	Out	Net	In	Out	Net
6:00		1	-1		1	-1		1	-1		1	-1
7:00		1	-2		1	-2						
8:00		3	-5		2	-4		2	-3		1	-2
9:00		3	-8		2	-6		1	-4		2	-4
	1			1			1			1		
10:00		3	-10		3	-8		2	-5		2	(-5)
	1			1								
11:00		2	(-11)		2	(-9)						
	2			3			1			2		
12:00		2	-11		2	-8		2	(-6)		1	-4
	2			3			2			1		
13:00		2	-11		2	-7		1	-5		2	-5
	3			3			2			2		
14:00		2	-10		2	-6		2	-5		2	-5
	2			2								
15:00		2	-10		2	-6						
	2			2			1			2		
16:00		1	-9		2	-6		2	-6		1	-4
	2			2			2			1		
17:00		2	-9		3	-7		1	-5		2	-5
	2			2			2			2		
18:00		1	-8		2	-7		1	-4		2	-5
	2			2								
19:00		1	-7		2	-7						
	2			1			1			2		
20:00		1	-6		1	-7		1	-4		1	-4
	3			2			2			1		
21:00		1	-4		1	-6		1	-3		1	-4
	2			1			2			1		
22:00			-2			-5			-1			-3
	2			1								
23:00			0			-4						
	1			1			1			1		
24:00			1			-3			0			-2
	1		+2	1		-2	1		+1	1		-1
TOTAL	30	28		28	30		18	17		17	18	
	58						35					

Trip Assignment C - Semi-Shuttle
(Shuttle Trips August Day)

Time	Van. Depot Coaches In	Out	Net	Tsawwassen Coaches In	Out	Net	Vict. Depot Coaches In	Out	Net	Swartz Bay Coaches In	Out	Net
6:00		0	0					0				
				0						0		
7:00		1	-1					0				
				1						0		
8:00		2	-3		(1)	0		2	-2			
	(1)			2						2		
9:00		3	-5		0(2)	0		1	-3		0(2)	0
	0(2)			3			0(2)			1		
10:00		3	(-6)		0(3)	0		2	-3		1	0
	0(3)			3			1			2		
11:00		2	-5		2(1)	0		2(1)	-5		2	0
	2(1)			2			2			2(1)		
12:00		1	-3		1	1		1(2)	(-6)		3	0
	1			1			3			1(2)		
13:00		1(1)	-4		2	0		1(1)	-5		3	0
	2			1(1)			3			1(1)		
14:00		1	-3		2	0		1	-3		2	0
	2			1			2			1		
15:00		1	-2		1	0		1	-2		1	0
	1			1			1			1		
16:00		1	-2		1	0		1	-2		1	0
	1			1			1			1		
17:00		1	-2		1	0		2	-3		1	0
	1			1			1			2		
18:00		1	-2		1	0		2	-4		1(1)	0
	1			1			1(1)			2		
19:00		1(1)	-3		1	0		1	-3		1(1)	0
	1			1(1)			1(1)			1		
20:00		1(1)	-4		2	0		1	-2		1	0
	2			1(1)			1			1		
21:00		1	-3		2	0		1	-2		1	0
	2			1			1			1		
22:00		(1)	-2		1	0		(1)	-2		1	0
	1			(1)			1			(1)		
23:00		(1)	-2		1	0		(1)	-2		1	0
	1			(1)			1			(1)		
24:00			-1		1	0			-1		1	0
	1		0				1		0			
TOTAL	19(7)	21(5)		21(5)	19(7)	1	21(4)	19(6)		19(6)	21(4)	0
				80(22)								

Trip Assignment C - Semi-Shuttle
(Shuttle Trips April Day)

	Van. Depot Coaches			Tsawwassen Coaches			Vict. Depot Coaches			Swartz Bay Coaches		
Time	In	Out	Net	In	Out	Net	In	Out	Net	In	Out	Net
6:00		0						0				
				0						0		
7:00												
8:00		1	-1					0				
				1						0		
9:00		1	-2		0(1)	0		1	-1		0	
	0(1)			1			0			1		
10:00		1	-2		(1)	0		2	(-3)		(1)	0
	(1)			1			(1)			2		
11:00			-1		0	1			-2		1	1
	0						1					
12:00		1(1)	(-3)		1	0		1	-2		1	0
	1			1(1)			1			1		
13:00		1	-3		2	0		1	-2		1	0
	2			1			1			1		
14:00		1	-2			1		2	-3		(1)	
				1			(1)			2		
15:00					1	1			-2		1	1
	1						1					
16:00		1(1)	-3		1	0		1	-2		1	0
	1			1(1)			1			1		
17:00		1	-3		2	0		1	-2		1	0
	2			1			1			1		
18:00		1	-2			1		1	-2			1
				1						1		
19:00					1	1					1	1
	1						1					
20:00		1	-2		1	0		1	-2		1	0
	1			1			1			1		
21:00		0	-1		1	0		1	-2		1	0
	1			0			1			1		
22:00		(1)	-1						-1			1
				(1)		0						
23:00		(1)	-2		1						1	0
	1			(1)			1					
24:00			-1		1	0			0		0	
	1		0				0		0			
TOTAL	12(2)	10(4)		10(4)	12(2)	5	10(2)	12		12	10(2)	5
					44(8)							

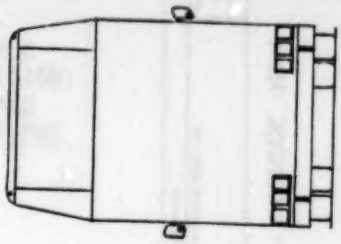
Trip Assignment D - Double-Deckers

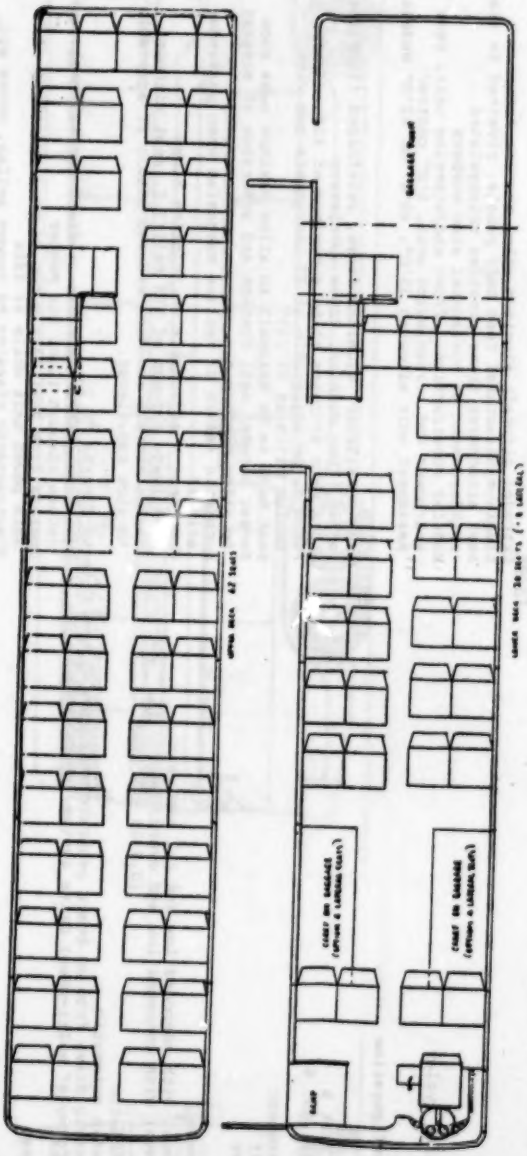
	AUGUST DAY						APRIL DAY					
	Van. Depot			Vict. Depot			Van. Depot			Vict. Depot		
	Coaches			Coaches			Coaches			Coaches		
Time	In	Out	Net	In	Out	Net	In	Out	Net	In	Out	Net
6:00		1	-1		1	-1		1	-1		1	-1
7:00		2	-3		1	-2						
8:00		3	-6		3	-5		2	-3		1	-2
9:00		4	-10		2	-7		2	-5		2	-4
10:00	1	4	-13	1	3	-9	1	2	-6	1	3	(-6)
11:00	1	3	(-15)	2	3	(-10)						
12:00	3	2	-14	3	2	-9	1	2	(-7)	2	2	-6
13:00	2	2	-14	4	2	-7	2	2	-7	2	2	-6
14:00	3	2	-13	4	2	-5	3	2	-6	2	2	-6
15:00	3	2	-12	3	2	-4						
16:00	2	2	-12	2	2	-4	2	2	-6	2	2	-6
17:00	2	2	-12	2	3	-5	2	1	-5	2	2	-6
18:00	2	1	-11	2	3	-6	2	2	-5	2	2	-6
19:00	2	2	-11	2	2	-6						
20:00	2	1	-10	2	1	-5	2	1	-4	2	1	-5
21:00	3	2	-9	2	2	-5	2	1	-3	1	2	-6
22:00	3		-6	1		-4	2		-1	2		-4
23:00	2		-4	2		-2						
24:00	1		-3	1		-1	1		0	1		-3
	2		-1	2		+1	2		+2	1		-2
TOTAL	34	35		35	34		22	20		20	22	
	69						42					

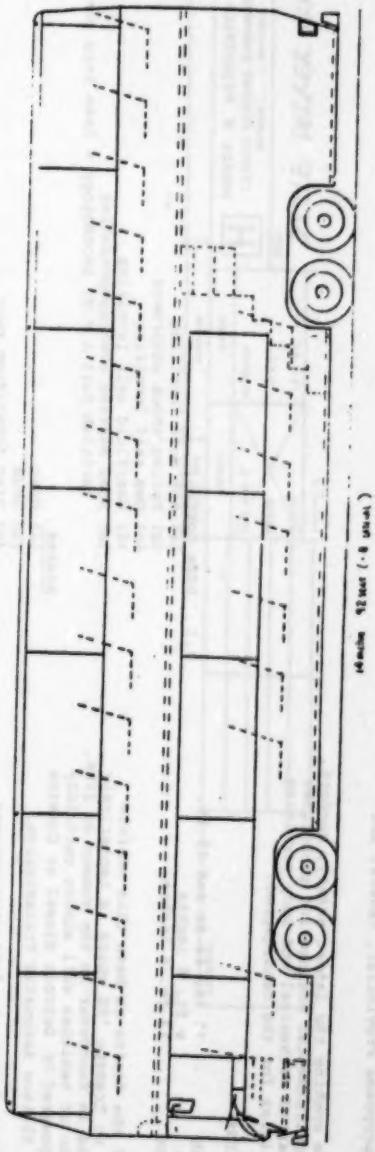
TRIP ASSIGNMENT - E MIXED FLEET (AUGUST DAY)

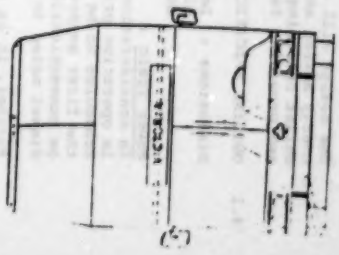
	Double-Decker Buses						Standard Buses					
	Van. Depot			Vict. Depot			Van. Depot			Vict. Depot		
	Coaches			Coaches			Coaches			Coaches		
Time	In	Out	Net	In	Out	Net	In	Out	Net	In	Out	Net
6:00								1	-1		1	-1
7:00								2	-3		1	-2
8:00		3	-3					0			4	-6
9:00		4	-7					0			3	-9
10:00		4	(-11)		2	(-2)	1	0	-2	1	2	-10
11:00							1	4	-5	2	4	(-12)
12:00				3	2	-1	4	3	-4	0	0	-12
13:00				4	2	1	3	3	-4	0	0	-12
14:00	2	2	-11	4	2	3	2	0	-2	0	0	-12
15:00							4	3	-1	4	3	-11
16:00	2		-9				0	2	-3	3	3	-11
17:00	2		-7		3	0	0	3	-6	3	0	-8
18:00	2		-5	2	2	0	0	2	(-8)	0	1	-9
19:00							3	2	-7	3	3	-9
20:00							3	2	-6	2	2	-9
21:00	3		-2				0	2	-8	3	2	-8
22:00	2		0				1		-7	2		-6
23:00							3		-4	2		-4
24:00							2		-2	2		-2
							2		0	2		0
TOTAL	13	13		13	13		29	29		29	29	
	26						58					

APPENDIX B
PCL's INITIAL DDB SKETCH AND SPECIFICATIONS









4.0 DESIGN CRITERIA

To incorporate available state-of-the-art technology in a double decker custom built service vehicle which will comply with the dimensional and weight constraints of existing and/or proposed Provincial, Federal and world markets.

The design will also combine the latest safety, comfort, energy saving and environmental engineering techniques whilst retaining ease of mechanical and body servicing and providing facilities for the handicapped.

4.1 OUTLINE SPECIFICATIONS

Dimensions :	Length	35 ft; 40 ft and 45 ft.
	Width	8 ft. 6 inches
	Height	13 ft. 6 inches

Power Train :
In consideration of the desire to have this vehicle in operation prior to Transpo '86 which is tentatively scheduled to be held in Vancouver in the summer of 1986, the first generation of vehicles will almost certainly be conventionally powered by Detroit diesel or Cummins diesel mated to an Allison Automatic Transmission.

Further, it is suggested that the following options be considered in the final planning stage so that they may be incorporated in future generations without major chassis or body modifications.

Engine Options
1. Fuel
(a) Diesel
(b) Propane
(c) Heat (stirling cycle)
(d) Hydrogen

2. Cylinder Configuration
(a) V8
(b) V6
(c) Horizontal flat 6
(d) Vertical straight 6

3. Power enhancement
(a) Turbocharger
(b) Supercharger

Transmission
1. Gearbox
(a) 5 speed manual with compound low and 1:1 top gear
(b) 6 speed manual with compound low and overdrive (0.8:1) top gear
(c) 6 speed automatic
(d) Variable ratio automatic
(e) Direct electric drive from on board generator/battery
(f) "Ferguson Formula" multi-wheel drive system/antiskid

2. Power Storage
(a) Flywheel
(b) Gas
(c) Battery (with 1(e)
(d) Heat (with engine 1(c))

Suspension
(a) Steel leaf
(b) Fibreglass leaf
(c) Steel coil
(d) Torsion bar
(e) Air bags
(f) Gas
(g) Gas/fluid

4.1 Ride Control
(a) Air self levelling
(b) Spring/shock absorbers
(c) Gas self levelling
(d) Gas/fluid self levelling
(e) Load sensing over-compensating (British Rail A.P.T. technology - lean into curve).

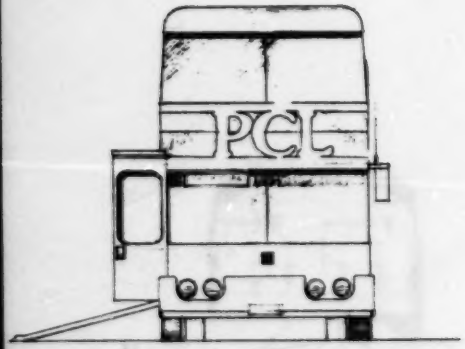
Brakes
(a) Disc
(b) Drum
(c) Disc front/drum rear
Braking system to be coupled with regenerative transmission.

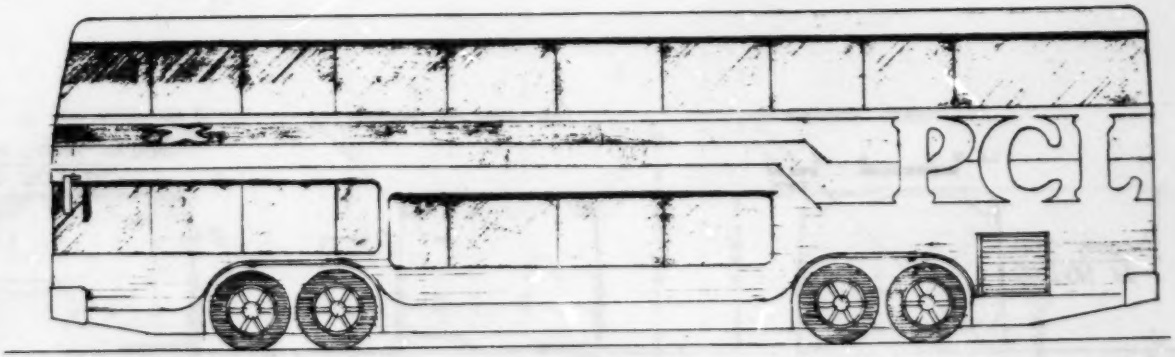
Frame
Extruded aircraft aluminum alloy section frame
Aluminum/structural foam body panels, rivetted to frame
Seat attachment frame provides triangulated reinforcement of horizontal side members
Modular construction : front end/steering unit, rear end/power and transmission unit, 5'0" centre/passenger unit allowing 35'0", 40'0" or 45'0" models.

Seats
Side cantilever, aluminum frame, reinforced fibreglass shell, foam cushion, Timme upholstery
Width over armrests to be a maximum of 40"
Pitch to be adjustable at 2" increments but with design pitch of 32"/36"
Seat back to be thinwall to allow maximum knee room
Recess between seat cushion and underside of armrest to allow maximum hip room
Automatic return of recline mechanism when passenger arises?
Foot rest - adjustable on friction hinge
Investigate the use of VIA Rail/T.C. seat without centre armrest and with reduced pitch, if adaptable to side cantilever.

Climate Control
Duct through frame members at floor and waist level, return through light bar member
Operate from auxiliary motor or on 2 cylinders of main power unit while at idle
Electrostatic cleaning to remove pollen, smoke etc.

Glass
3/4" air gap double safety glass with photochromatic grey on all windows behind driver





APPENDIX C
BASELINE DESIGN:
SKETCH AND
SPECIFICATIONS

ITEM	QTY	PART NO.	DESCRIPTION

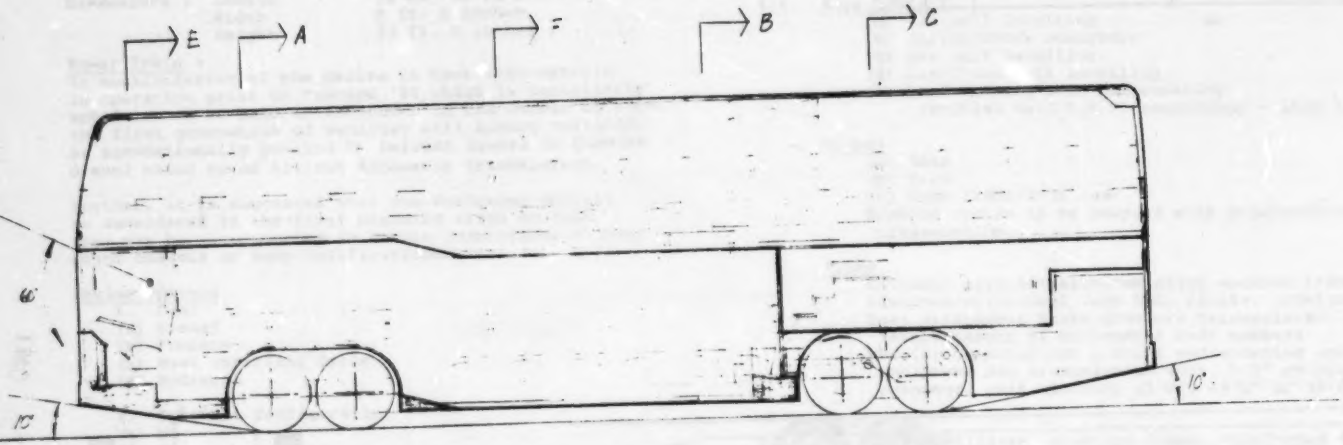
METRIC	INCHES
DECIMALS	
HOLES	.X ±
SHAFTS	.X X ±
ANGLES ±	.X X X ±

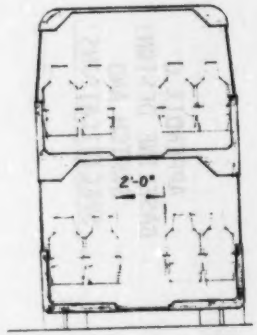
APPROVAL

H HOVEY & ASSOCIATES LTD.
VEHICLE SYSTEMS ENGINEERING
OTTAWA ..... ONTARIO

TECHNICAL DATA LIST

TITLE
DOUBLE DECKER COACH - EXTERIOR VIEW



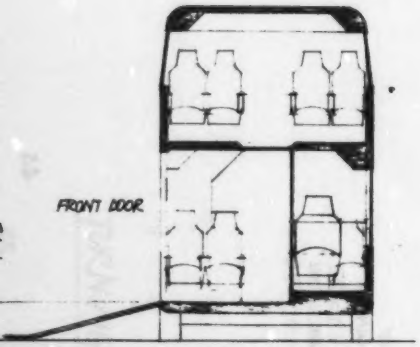


SECTION FF
(TYPICAL SECTION)

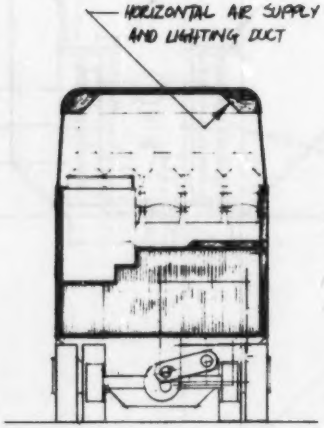
E A F B C

SECTION DD
(LONGITUDINAL SECTION)

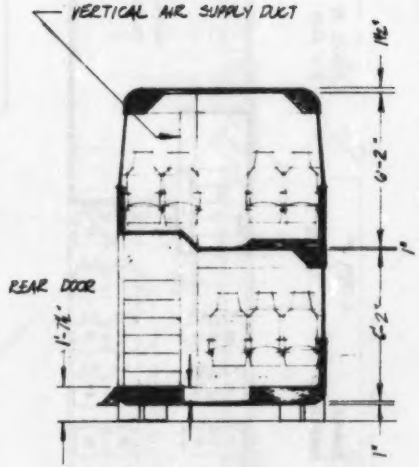
SCALE:
0 1 2 4 8 FT.



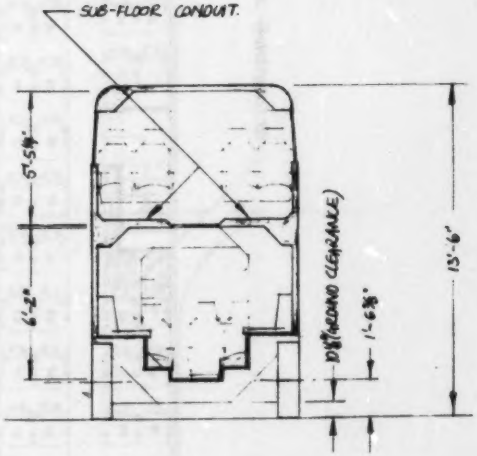
SECTION EE



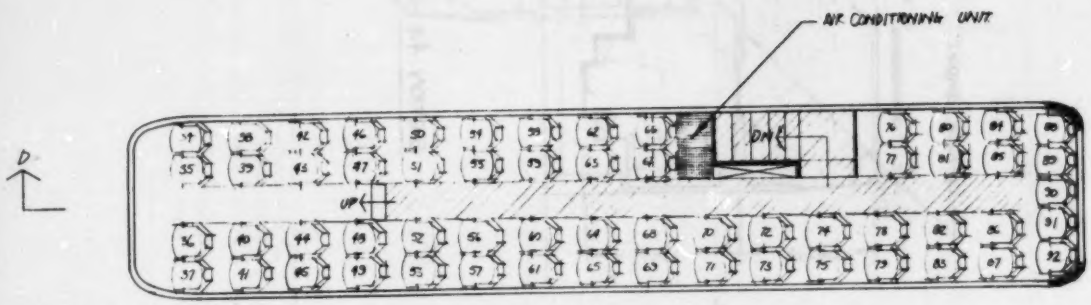
SECTION CC

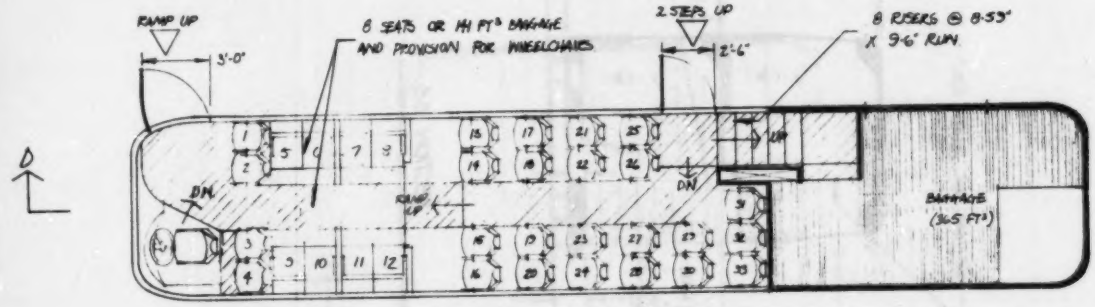


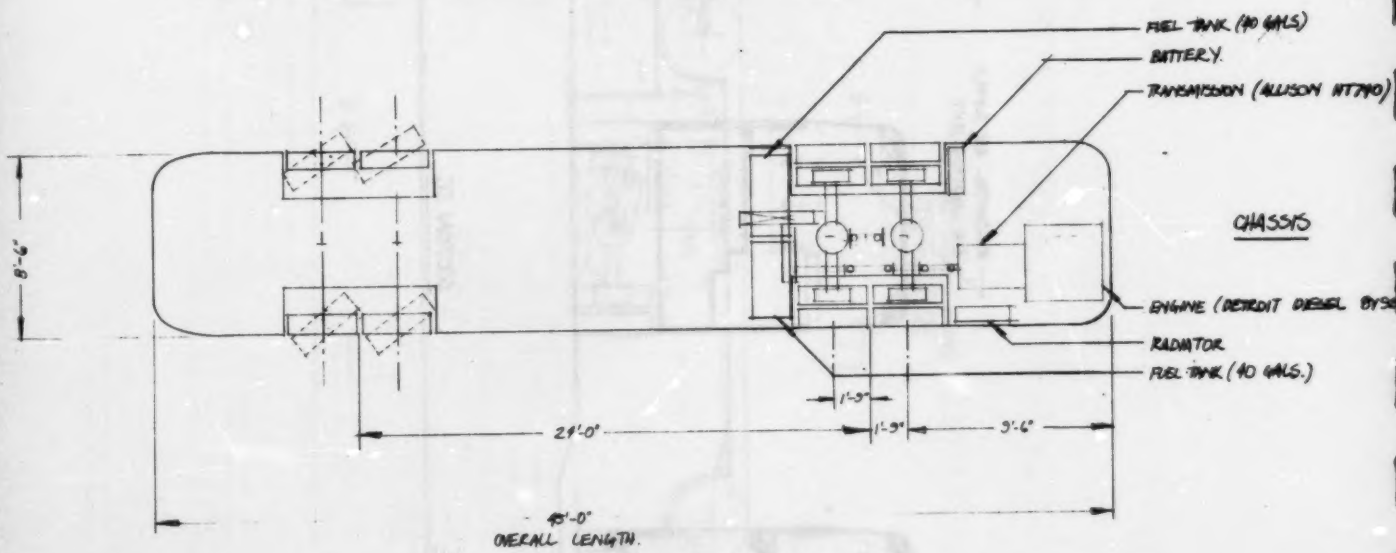
SECTION BB

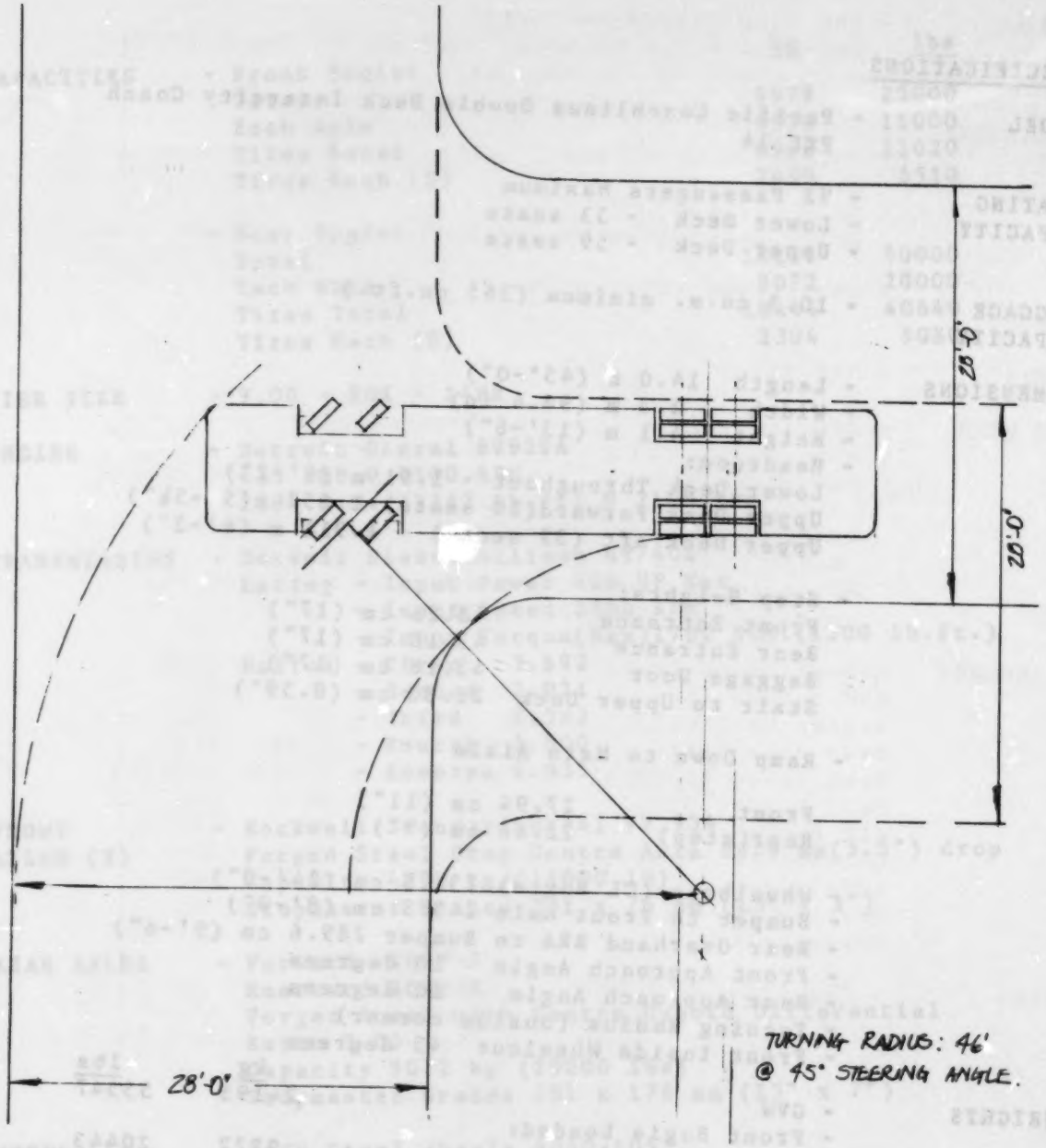


SECTION AA


AIR CONDITIONING UNIT
D
D
UPPER LEVEL


RAMP UP
3'-0"
8 SEATS OR 144 FT³ BAGGAGE AND PROVISION FOR WHEELCHAIRS
2 STEPS UP
2'-6"
8 RISERS @ 8.53" X 9'-6" RUN
D
D
LOWER LEVEL
DN
UP
RAMP UP
BAGGAGE (365 FT³)


FUEL TANK (90 GALS)
BATTERY
TRANSMISSION (ALLISON MT740)
CHASSIS
ENGINE (DETROIT DIESEL 8V92
RADIATOR
FUEL TANK (90 GALS.)
8'-6"
1'-9"
24'-0"
1'-9"
9'-6"
45'-0"
OVERALL LENGTH.



TURNING RADIUS

SPECIFICATIONS

MODEL - Pacific Coachlines Double Deck Intercity Coach PCL 14

SEATING CAPACITY
- 92 Passengers Maximum
- Lower Deck - 33 seats
- Upper Deck - 59 seats

BAGGAGE CAPACITY - 10.3 cu.m. minimum (365 cu.ft.)

DIMENSIONS
- Length 14.0 m (45'-0")
- Width 2.5 m (98.4 in)
- Height 4.1 m (13'-6")
- Headroom:
  Lower Deck Throughout - 1.91 m (6'-2")
  Upper Deck Forward(20 seats)-1.657 m(5'-5½")
  Upper Deck Aft (39 seats) - 1.911 m (6'-2")

- Step Heights:

Front Entrance	48.26 cm (17")
Rear Entrance	43.18 cm (17")
Baggage Door	43.18 cm (17")
Stair to Upper Deck	21.82 cm (8.59")

- Ramp Down to Main Aisle

Front	27.94 cm (11")
Rear(step)	22.86 cm (9")

- Wheelbase (CL Bogie) 731.5 cm (24'-0")
- Bumper to Front Axle 243.8 cm (8'-0")
- Rear Overhand RRA to Bumper 289.6 cm (9'-6")
- Front Approach Angle 10 degrees
- Rear Approach Angle 10 degrees
- Turning Radius (ouside corner)
- Front Inside Wheelcut 45 degrees

WEIGHTS

	kg	lbs
- GVW	24195	55547
- Front Bogie Loaded:		
Total	9272	20443
Per Axle	4636	10222
Per Wheel (S)	2318	5111
- Rear Bogie Loaded:		
Total	15927	35114
Per Axle	7964	17557
Per Wheel (D)	1991	4389

		kg	lbs
CAPACITIES	- Front Bogie:		
	Total	9979	22000
	Each Axle	4990	11000
	Tires Total	4998	11020
	Tires Each (S)	2499	5510
	- Rear Bogie:		
	Total	18144	40000
	Each Axle	9072	20000
	Tires Total	18444	40640
	Tires Each (D)	2304	5080

TIRE SIZE - 9.00 - 20R - 14PR

ENGINE - Detroit Diesel 8V92TA
435 BHP @ 2100 RPM
1684 N.M. (1242 lb.ft) @ 2100 RPM

TRANSMISSION - Detroit Diesel Allison HT740D
Rating - Input Power 424 HP Net
- Input Speed 2800 RPM
- Input Torque(Max)1762 N.M.(1300 lb.ft.)
Ratios - First 3.692
- Second 2.021
- Third 1.383
- Fourth 1.000
- Reverse 6.035

FRONT AXLES (2) - Rockwell Standard Model FF 934
Forged Steel Drop Centre Axle 88.9 mm(3.5") drop
Capacity 4990 kg (11000 lb)
Stopmaster Brakes 381 x 76 mm (15" x 3")

REAR AXLES - Forward SQHP-F
Rearward SQHP-R
Forged Steel with Centre Hypoid Differential
Ratio 3.55
Capacity 9072 kg (20000 lbs)
Stopmaster Brakes 381 x 178 mm (15" x 7")

WHEELS - Budd Steel Wheels 6040-105
Size 20 x 7.50
Offset - 165 mm (6½ in)
Dual Spacing 330 mm (13 in)
Capacity Each - 2740 kg (6040 lbs)

For Tube Type Tires

TIRES - Michelin 9.00 R 20 - 14 PR XZA or equivalent
Capacity (S) 2499 kg, 5510 lbs
(D) 2304 kg, 5080 lbs

../2

STEERING - TRW Ross HydraPower HFB64
Integral Power Steering Gear on Two Front Axles with Wheel Cut 45 degrees.

SUSPENSIONS - ARC (Active Ride Control) (tentative)
Automatic Levelling using Hydraulic Struts
Gas Springs
Roll Control
Axles Controlled by Torque Rods and Panhard Rods

FUEL CAPACITY - 182 Litres (40 Imp. Gal)

BATTERY - SAE 8D

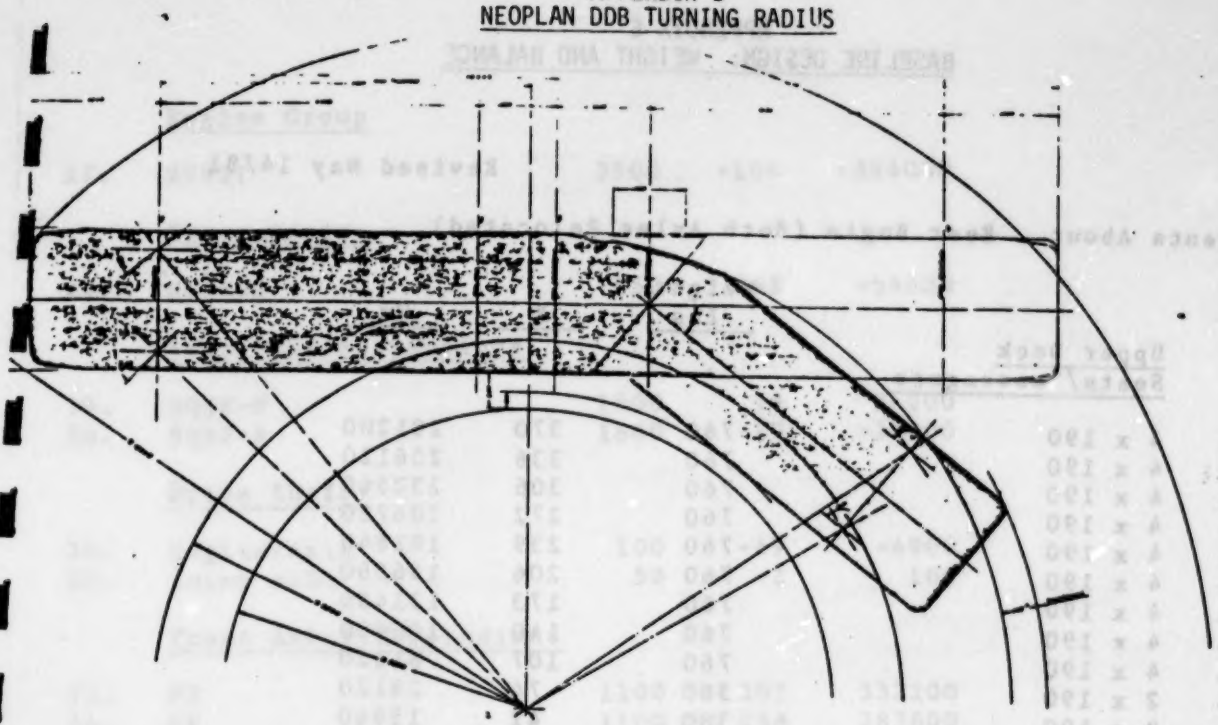
COACH WORK - Aluminum Alloy Rivetted Construction
Polyurethane Foam Insulated
Passenger Windows - double Glazed, Tinted, Heat absorbing, Safety Glass
Driver's Window - Opening Type, Heat Treated, Safety Glass
Windshields Upper and Lower Deck - Curved Duo-plate Laminated Safety Glass

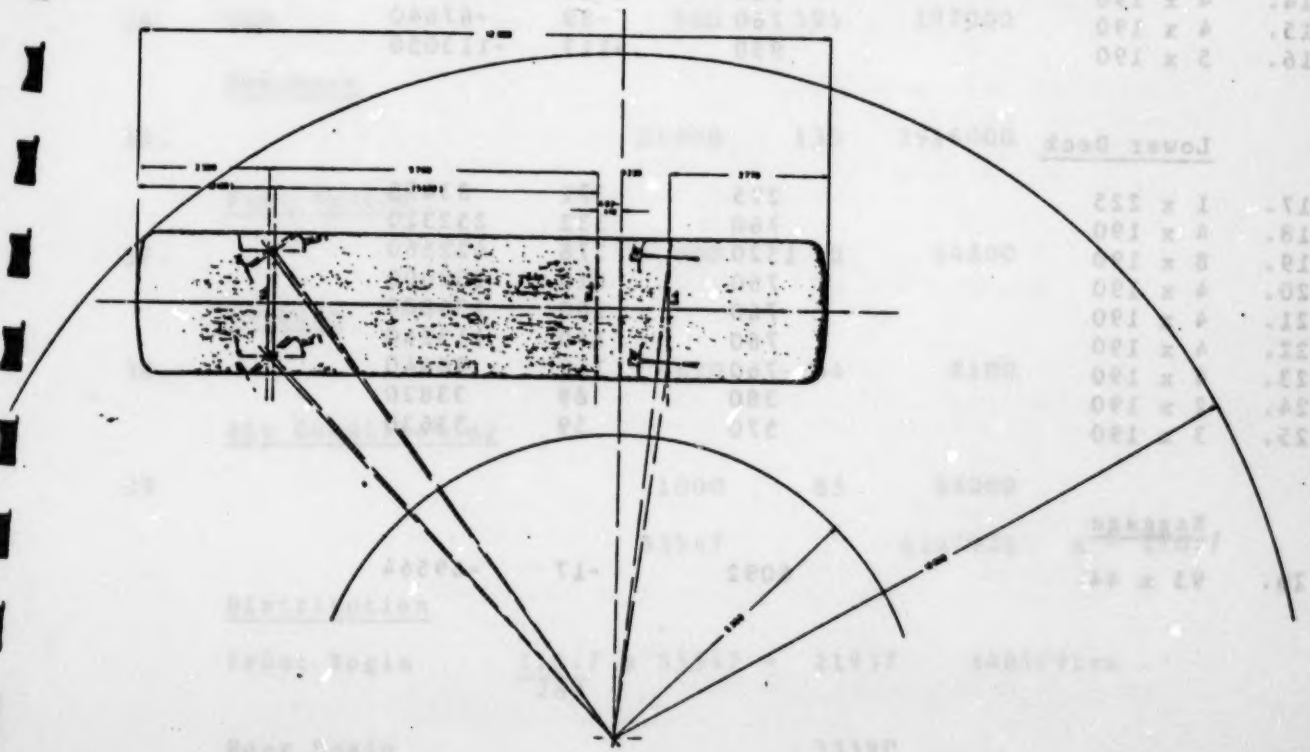
PERFORMANCE

Transmission Ratio	3.69	2.02	1.38	1.00
GVW - 1000 lb	56	56	56	56
Engine HP (Net)	392	392	392	392
Rear Axle Ratio	3.55	3.55	3.55	3.55
Road Speed Km,(MPH)	29(18)	53(33)	77(48)	108(67)
Roll Resist HP	25	52	86	130
Air Resist HP	3	20	60	149
Chassis Friction HP	26	26	26	26
Level Road HP	54	98	172	306
Reserve HP	338	294	220	86
Gradeability %	12.6	6.0	3.1	0.9

GENERAL - Complies with MVSS - United States
CMVSS - Canada
SAE Standards

APPENDIX D
NEOPLAN DDB TURNING RADIUS





Notwendige Verkehrsfläche:
Gelenkzug 45,00 qm
Doppeldecker 30,00 qm

Necessary traffic-area:
articulated bus 45,00 m²
double-decker 30,00 m²

APPENDIX E
BASELINE DESIGN: WEIGHT AND BALANCE

Revised May 14/81

Moments About Rear Bogie (Both Axles Relocated)

		Weight lbs	X	Wx
	Upper Deck Seats/Passengers			
1.	4 x 190	760	370	281200
2.	4 x 190	760	336	256120
3.	4 x 190	760	306	232560
4.	4 x 190	760	272	206720
5.	4 x 190	760	239	181640
6.	4 x 190	760	206	156560
7.	4 x 190	760	173	131480
8.	4 x 190	760	140	106400
9.	4 x 190	760	107	81320
10.	2 x 190	380	74	28120
11.	2 x 190	380	42	15960
12.	2 x 190	380	10	3800
13.	4 x 190	760	-25	-19000
14.	4 x 190	760	-58	-44080
15.	4 x 190	760	-89	-67640
16.	5 x 190	950	-119	-113050
	Lower Deck			
17.	1 x 225	225	371	83475
18.	4 x 190	760	332	252320
19.	8 x 190	1520	278	422560
20.	4 x 190	760	210	159600
21.	4 x 190	760	180	136800
22.	4 x 190	760	140	113240
23.	4 x 190	760	119	90440
24.	2 x 190	380	89	33820
25.	3 x 190	570	59	33630
	Baggage			
26.	93 x 44	4092	-17	-69564

	Engine Group			
27.	8V92T	3500	-104	-364000
	Transmission			
28.	HT740D	950	-68	-64600
	Rear Axle/Suspensions			
29.	SQHP-F	1800	19	34200
30.	SQHP-R	1800	-19	-34200
	Drive Shafts			
31.	Engine/Axle	100	-49	-4900
32.	Inter Axle	50	-2	100
	Front Axles/Suspensions			
33.	FF	1100	302	332200
34.	FF	1100	258	283800
	Steering			
35.	TRW	500	394	197000
	Bodywork			
36.		21600	135	2916000
	Fuel System			
37.		900	72	64800
	Battery			
38.		150	-54	8100
	Air Conditioning			
39		1000	85	85000
		55547		6147931 x - 110.7

Distribution

Front Bogie $\frac{110.7}{280} \times 55547 - 21957$ 5489/Tire

Rear Bogie 33590

APPENDIX F

Future Trends
(Annotated Bibliography)

A number of SAE papers are included in the original report received from Hovey & Associates (filed at the TDC Library). Abstracts of these papers follow:

780293 Large Buses and the Townobile Electric City Transit System.

Although this paper is directed primarily at transit operations, it is particularly interesting and is therefore included.

The comments on page 3 concerning diesel bus systems suggest that we may be somewhat mesmerized by our existing systems in spite of their relatively high "down time" and costly service.

The trackless trolley concept has been extended using a dual-mode concept, using batteries and charging stations to provide "without the wires" capability.

The concept is worth examining with reference to the Vancouver-Victoria operation, but would of course depend upon overall acceptance of the idea in the transit systems of the principal cities involved.

780294 A Diesel - Electric Hybrid Bus

Attention is drawn to the Summary and Conclusions on page 11.

The possibility of selecting smaller components partly offsets the redundancy of the hybrid system, and the fuel consumption can be halved.

However, the components must be carefully matched to the driving cycle, and the Vancouver-Victoria run may have too much continuous high speed running to make it attractive.

790029 Fabrication and Assembly of a Graphite Fiber Reinforced Plastic Vehicle

790031 Design and Fabrication of Automotive Components in Graphite Fiber - Reinforced Composites

These two papers are included simply because they are topical due to general interest in the possibilities of these materials.

790129 Field Experience With the Detroit Diesel Allison 404/505 Industrial Gas Turbine Engines

This paper is a progress report which indicates good progress but gives no indication that gas turbines should be given serious consideration for the current project.

790164 Minimizing the Weight of Aluminum Body Panels

Included to illustrate current technology for efficient design in aluminum.

790304 AM General/Man Articulated Bus

This paper gives a good insight into this design, which is an obvious comparison to the current project.

790305 Improvement of City Bus Fuel Economy Using a Hydraulic Hybrid Propulsion System

Here is another approach to a hybrid power system with hydraulic accumulator energy storage. It emphasizes that such systems do not work well with open road driving patterns involving relatively high speed and few stops.

790400 Performance of Aluminum Automotive Radiators

Here Dow Corning announce a non-organic coating but which uses an organic solvent as a carrier for application.

It appears to have superior qualities applicable to bus surfaces, being a clear, bright surface protection superior to anodizing.

791037 Hybrid Graphite Fiber Composites for the Automotive Industry

This paper gives an insight into the types and applications of graphite fiber.

It also relates price to volume and forecasts the trend of usage in the automotive industry.

It is still very expensive but the price is dropping relatively.

"Hybrid graphite fiber construction is currently viewed as a final approach to maximum weight reduction."

791039 Design, Fabrication, and Evaluation of Experimental Advanced Composite Truck Frame Rails

See the conclusions on page 9. This clearly indicates the potential of advanced composite materials for high strength low weight applications.

APPENDIX G

DOUBLE-DECK BUS: 2000 AND BEYOND *

1.0 The report prepared for PCL by Hovey entitled "The Feasibility of Designing a Double Decker Intercity Bus for Canadian Manufacture" presented a state-of-the-art design, with innovation in two principal areas:

1.1 the structure, in which the novelty resides in the use of heavy sidewalls and thin floors, as dictated by headroom requirements and safety;

1.2 the suspensions, which incorporate active ride using an air/oil system for stability and height control.

2.0 However, a design aimed at use up to and beyond the year 2000 should, and could make a quantum jump in certain other areas:

2.1 The vehicle dynamics.
The present rear engine configuration brings about a weight distribution with a two-thirds bias to the rear bogie. This combined with rear wheel drive causes a tendency toward oversteer and loss of control in skid situations, typical of rear-end heavy vehicles.
Modern automobiles favour a 55% weight bias to the front axle, and front wheel drive in conjunction with this optimizes traction, vehicle dynamics and handling. Such vehicles have recognized advantages in slippery conditions and are not prone to oversteer and loss of control. This concept is equally attractive for the double-decker bus.

* An edited extract from a letter dated October 20, 1981 to H. Olafson, Vice President of Pacific Coach Lines from L. Walker of Hovey & Associates (1979) Ltd.

2.2 Safety

Following the review of photographs of a major accident involving a PCL bus in which the driver and several front passengers were killed and the front half was totally demolished. Placing the engine in the front seems desirable since it is felt that heavy masses interposed between the obstacle and the passenger envelope, combined with a carefully designed structural cage could achieve higher survivability in a major accident.

2.3 Driver Position

Raising the driver considerably would improve visibility and provide much greater saftey to the driver.
To achieve all this in an intercity bus within the dimensional constraints involves departure from the state-of-the-art concept as presented in the feasibility study, in some areas. A proposal is presented herewith and is supported by the enclosed sketches.

3.0 Proposal

3.1 The vehicle is configured as shown in sketches showing a 41 ft (12.5 m) and a 46 ft (14 m) version.

3.2 A diesel-electric drive system is proposed, with the engine/a.c. generator mounted transversely at the front of the vehicle, as a unit "pod".

3.3 The driver's floor is at the level of the top of the wheel arches, or may be placed higher yet if desired.

3.4 The front and rear axles are moved rearward, to provide space for the power unit and the front door, and to help equalize weight distribution.

3.5 Inboard mounted electric induction motors are provided for each wheel, four front and four rear, all wheels driving. The motors are frame mounted, and drive the wheels through universal drive-shafts, with planetary reductions in the hubs, or at the motor output shaft.

3.6 Each wheel is independently sprung using an active ride control system(such as air/oil).
There are eight wheels, identical front and rear. The tire size is 10x20(tentatively). Each wheel is provided with disc type air brakes.

3.7 The space above the axles, both front and rear, is consigned to baggage or parcels. (The floor height in these areas, because of the suspension mechanisms and the electric motors, limits headroom). Access to the forward baggage space is via the front door, and to the rear compartment, by a rear door. (Side compartment doors if preferred).

3.8 Passenger entry is via the rear side door, for both decks. 20 passengers are accommodated on the lower deck and 56 on the upper deck, total 76 in the 46 ft (14m) version, 68 in the 41 ft (12m) version.

3.9 Headroom of 6 ft. 2 in. is provided throughout, on both passenger decks.

3.10 Weight distribution will be approximately equal on all wheels, with a bias of about 5% to the front.

3.11 The upper deck loses the front row of seats due to the raising of the driver's position. This provides opportunity for aerodynamic and styling changes. Reference to Appendix I p 3 of our report indicates that aerodynamic drag accounts for approximately 150 hp at 65 mph. A one-third reduction in drag co-efficient could save $10,000 a year in fuel costs.
(50 hp @ .4 lbs/hr ÷ 8 lbs/gallon = 2..5 gph
2.5 gph x 2000 hrs x $2.00/gallon = $10,000)

3.12 The electric drive concept is as follows:

A diesel engine driven alternator provides energy for individual wheel motors. Speed is controlled by a frequency synthesizer. Thus it is possible to operate the engine at constant speed while varying the wheel speed. Use of high frequency is expected to enable the size of electrical components to be minimized. Small high speed motors may be designed into the wheels but more likely would be chassis mounted, driving through planetary reduction gears to (or in) the hubs.
The use of individual wheel motors eliminates the need for axle differential gears, or other positive traction devices. The principal problems involve the speed range available through frequency control, (0 to 8000 rpm minimum); whether motors can be designed to run at these speeds; and whether sufficient torque rise can be designed into an induction motor to give adequate gradeability at the lower speeds. I have placed these questions before the engineering

department of an electrical motor and frequency synthesizer manufacturer. Although at this time no quantitative study has yet been initiated, the reply is tentatively affirmative, that it can be done. The requirements are summarized below:

Engine hp gross = 430 hp
Main alternator output = 292 kw
Power per wheel = $\frac{292}{8}$ = 36.5 kw

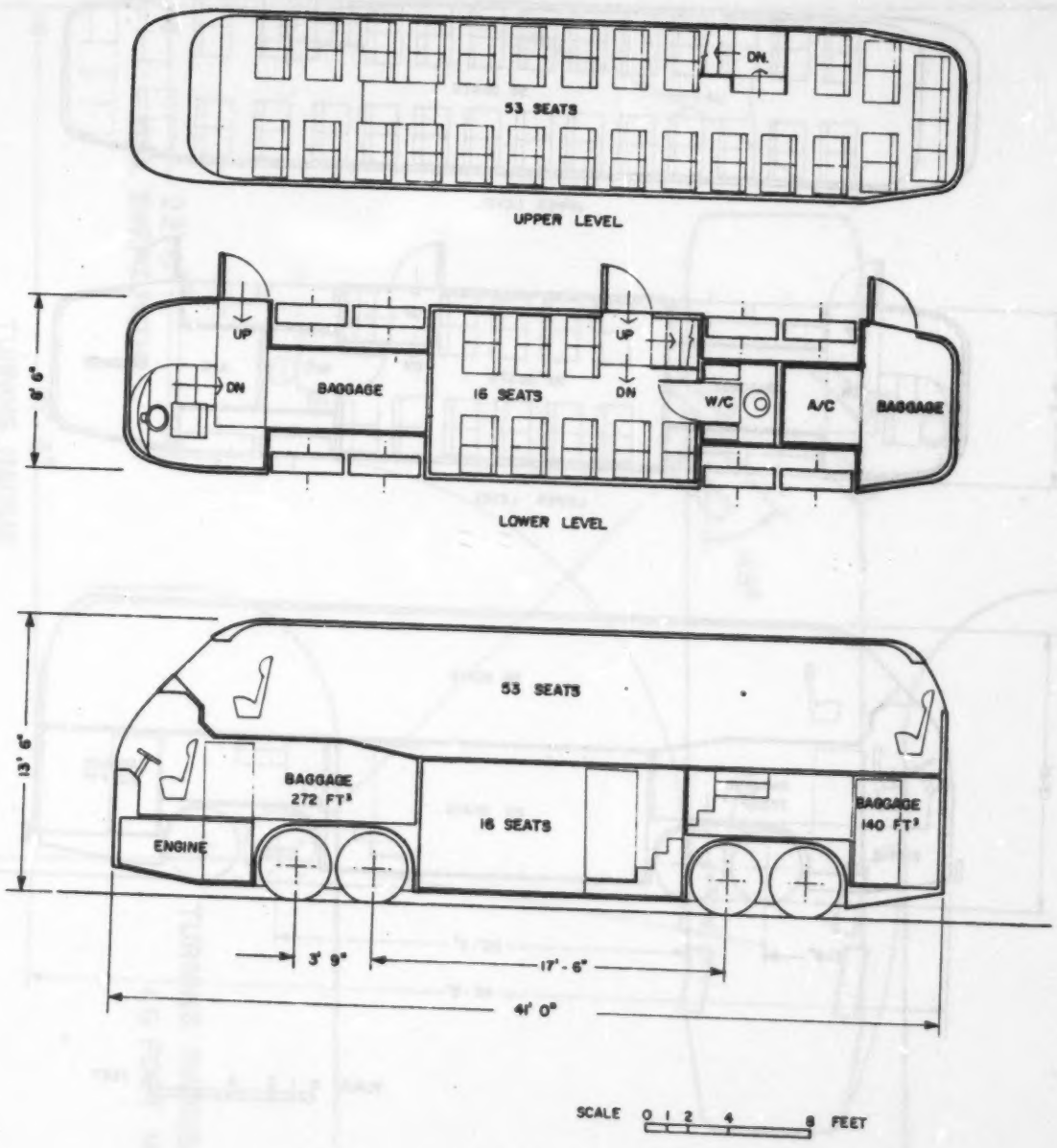
Torque @ wheel:
@ 65 mph = 481 lbs.ft.
@17.6 mph = 1384 lbs.ft.
Torque rise = $\frac{1384}{481}$ = 2.8

Wheel rpm:
@ 65 mph = 535 rpm
@ 17.5 mph = 148 rpm
Assuming planetary final reduction = 15:1
Motor rpm:
@ 65 mph = 8025 rpm
@ 17.6 mph = 2220 rpm

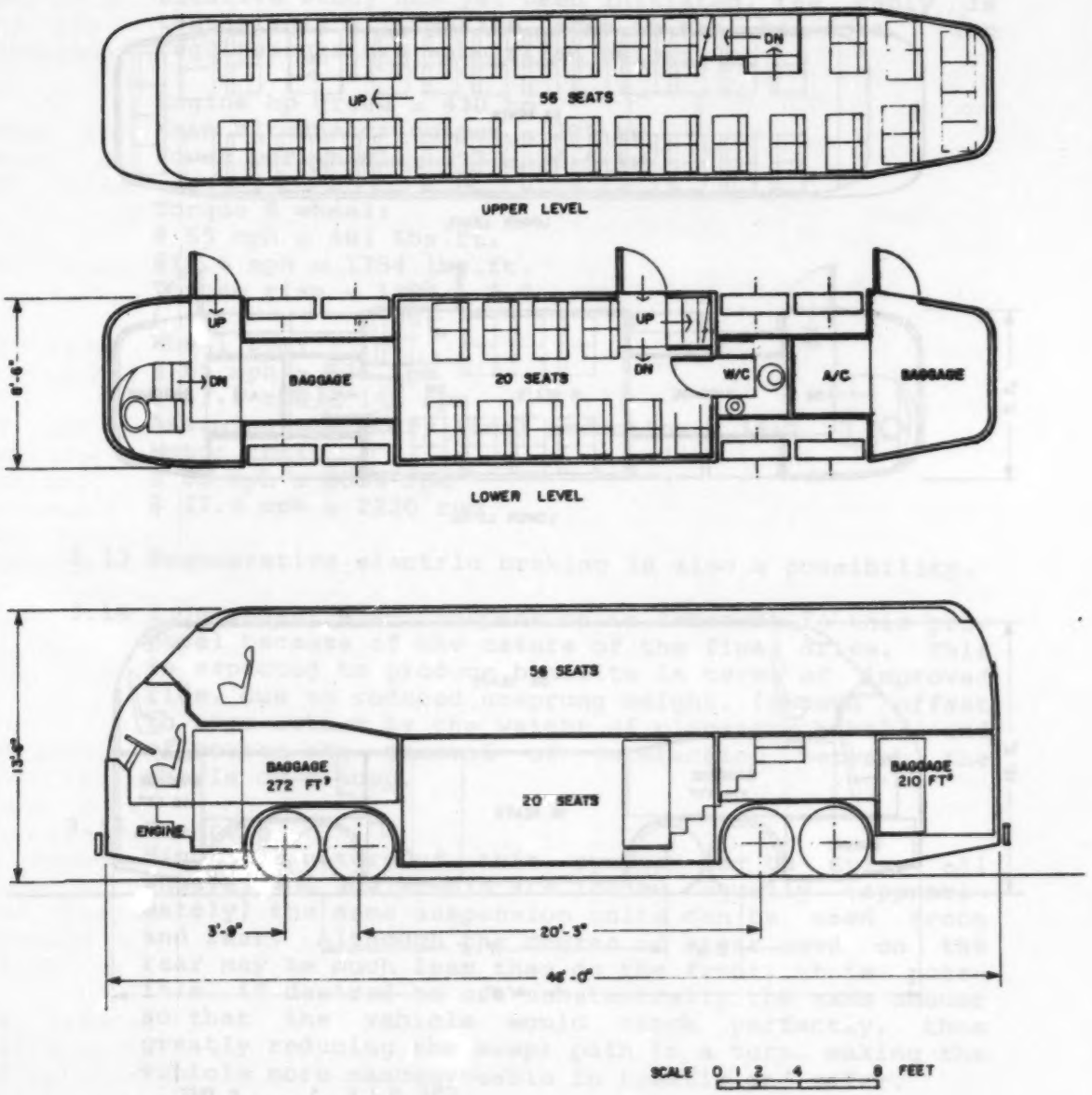
3.13 Regenerative electric braking is also a possibility.

3.14 Independent Wheel Suspension is inherent in this proposal because of the nature of the final drive. This is expected to produce benefits in terms of improved ride, due to reduced unsprung weight, (though offset to some extent by the weight of planetary hubs); and of course the removal of interaction between the wheels on a bump.

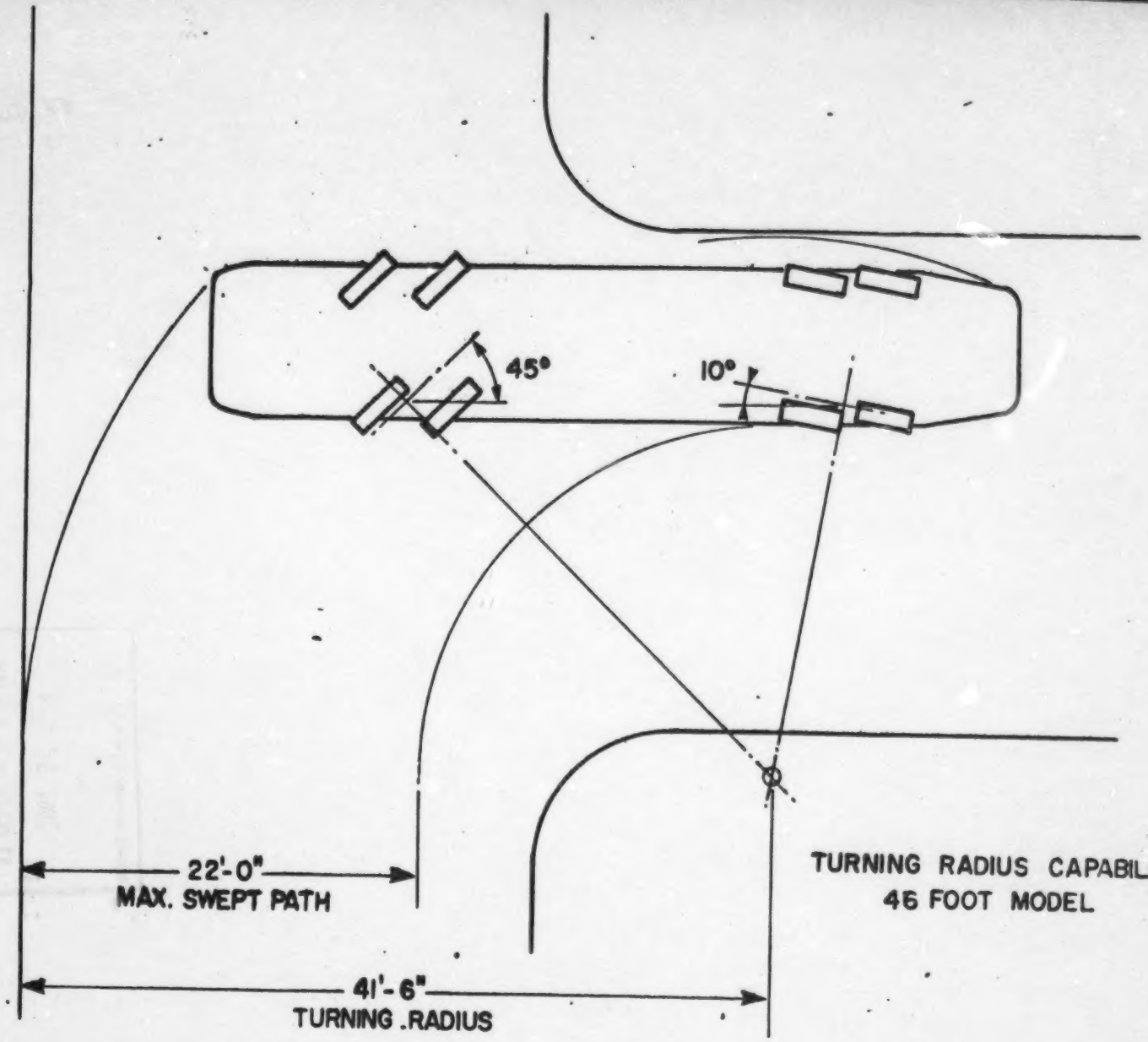
3.15 Steering
Since the nature of this system is to drive all wheels, and the wheels are loaded equally (approximately) the same suspension units can be used front and rear. Although the degree of steer used on the rear may be much less than on the front, it is possible, if desired to use substantially the same amount so that the vehicle would track perfectly, thus greatly reducing the swept path in a turn, making the vehicle more manoeuvreable in traffic and safer.


53 SEATS
DN
UPPER LEVEL
UP
DN
BAGGAGE
16 SEATS
UP
DN
W/C
A/C
BAGGAGE
8' 6"
LOWER LEVEL
53 SEATS
13' 6"
BAGGAGE
272 FT³
ENGINE
16 SEATS
BAGGAGE
140 FT³
3' 9"
17' - 6"
41' 0"
SCALE 0 1 2 4 8 FEET

41' MODEL


UP
DN
56 SEATS
UPPER LEVEL
UP
DN
BAGGAGE
20 SEATS
UP
DN
W/C
A/C
BAGGAGE
LOWER LEVEL
56 SEATS
BAGGAGE
272 FT³
20 SEATS
BAGGAGE
210 FT³
ENGINE
3'-9"
20'-3"
46'-0"
SCALE 0 1 2 4 8 FEET

46' MODEL



TURNING RADIUS CAPABILITY
45 FOOT MODEL